SAFE RAILWAY WORKING

A TREATISE ON

RAILWAY ACCIDENTS: THEIR CAUSE AND PREVENTION

WITH A DESCRIPTION OF MODERN APPLIANCES AND SYSTEMS

BY

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Capio Lumen

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TO

P. S. MACLIVER, Esq.,

PRESIDENT,

EDWARD HARFORD, Esq.,

GENERAL SECRETARY,

AND TO THE MEMBERS

OF

The Amalgamated Society of Railway Servants,

THIS VOLUME

IS

Dedicated

BY

THE AUTHOR.

PREFACE.

Several members of both Houses of Parliament, and others interested in the safe and proper working of railways, having recently applied to the Engineering Department of the Amalgamated Society of Railway Servants for information relating to the causes of the various so-called railway accidents, also as to the alterations, improvements, and appliances which are considered absolutely essential to the safety of the general public and of the railway servants, a list of twenty-three necessary requirements has been drawn up which will have to be adopted and brought into general use before any great improvement in railway safety can be looked for or expected.

At the expressed desire of railway officials, servants, and passengers, the author has been induced to prepare the present work to explain and illustrate the various mechanical appliances which conduce to the safety of railway travelling.

Upon a very recent occasion it was stated in the House of Commons by Mr. Mundella, then President of the Board of Trade, that the railway servants were the greatest sufferers by railway accidents, since among

them there was an amount of death and desolation which the House could hardly realise, and which was simply appalling. In eleven years, he said, 6,584 servants had been killed and 26,024 injured—a loss equal to that of many battles.

The author, since he entered the engineering profession twenty years ago, has devoted much time and attention to the examination of all appliances for railway safety; and as Consulting Engineer to the Amalgamated Society of Railway Servants, it is now his duty to examine, consider, and report upon the circumstances attending every accident, and the new or improved safety appliances necessary to prevent such occurrences in future. The views and opinions expressed in this volume are, therefore, based upon experience derived from a personal examination of the line and rolling stock after the various accidents, and the whole of the cases recorded in Chapter VII., under the heading of "Railway Servants and the Law," are those in which the author was either engaged or interested on behalf of the men implicated.

CLEMENT E. STRETTON.

40, SAXE-COBURG STREET, LEICESTER.
November, 1886.

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SAFE RAILWAY WORKING.

CHAPTER I.

SUMMARY OF ACCIDENTS ON RAILWAYS DURING THE YEAR 1885 AS REPORTED TO THE BOARD OF TRADE.

35 COLLISIONS between passenger trains or parts thereof.

53 collisions between passenger trains and goods trains.

22 collisions between goods trains or parts thereof.

65 cases of passenger trains or parts thereof leaving the rails.

9 cases of goods trains or parts thereof leaving the rails.

11 cases of trains travelling in the wrong direction through facing points.

14 cases of trains running into stations at too high a speed.

126 cases of trains running over cattle.

48 instances of trains running through gates at level-crossings.

377 failures of axles.

3 failures of brake apparatus.

6 failures of couplings.

920 failures of tyres.
1 failure of a wheel.
3 failures of ropes used in working inclines.
2 failures of bridges.
287 broken rails.
9 cases of flooding of permanent way.
8 slips in cuttings or embankments.
10 fires in trains.

The necessity for high platforms and continuous footboards is plainly shown by the fact that no less than 25 passengers were killed and 49 injured by falling between carriages and platforms.

17 passengers were killed and 470 injured by falling on to platforms, ballast, &c.

Foot-bridges over, or tunnels under, the railways are much required at many stations and crossings; 35 persons were killed and 11 injured whilst passing over the line at stations, and 58 killed and 16 injured whilst passing over level-crossings not at stations.

The number of railway servants killed and injured is again enormous; a very large proportion of these accidents occur during shunting operations and the marshalling of trains.

Altogether the number of persons killed and injured on railways in the United Kingdom in the course of public traffic during the year ending 31st December, 1885, as reported to the Board of Trade, was as follows:—

PERSONS KILLED AND INJURED, 1885.

—	Year 1885.		Total for corresponding period in 1884.	
	Killed.	Injured	Killed.	Injured.
Passengers.				
From accidents to trains, rolling stock, permanent way, &c.	6	436	31	864
By accidents from other causes	96	693	104	627
Servants of Companies or Contractors.				
From accidents to trains, rolling stock, permanent way, &c.	13	81	23	115
By accidents from other causes	438	2,036	523	2,204
Persons passing over railways at level-crossings	58	21	65	27
Trespassers (including suicides)	305	126	348	187
Other persons not coming in above classification	41	74	40	76
Total	957	3,467	1,134	4,100

NOTE.—In addition to the above, the Companies have, in pursuance of the Act of 1871, reported other accidents which occurred on their premises, and the total number of personal accidents reported to the Board of Trade during the year 1885 amount to 997 persons killed and 7,022 injured.

SUGGESTIONS FOR SAFE RAILWAY WORKING (MADE IN REPLY TO NUMEROUS INQUIRIES) BY THE AMALGAMATED SOCIETY OF RAILWAY SERVANTS OF THE UNITED KINGDOM, JANUARY, 1886.

1. It goes without saying that bridges, tunnels, stations, permanent way, and works must be properly constructed and efficiently maintained.

2. All railways ought to be worked on the absolute block system, *strictly carried out*, so that no two trains of any kind shall ever be in one section at one time.

3. The block and interlocking systems should be electrically combined and controlled, so that the safety of a block section shall be under the control of two signalmen.

4. The block working at all junctions should be arranged so that no two trains which can foul each other at the points and crossings shall ever be allowed to approach a junction at one and the same time. All sidings and goods lines joining main lines should be provided with properly interlocked safety points.

5. Efficient signals should be employed, and the posts ought always to be placed upon the left-hand side of the line to which they refer. At large stations and junctions short arms or discs should be provided for controlling shunting operations, in order to avoid that most dangerous but common practice, hand signalling.

6. One code of block system regulations, and one pattern of signal, should be adopted throughout the kingdom. All distant signals of that old-fashioned disc or board pattern should be at once replaced by the usual "swallow-tail" arm. A red light should be the *only* danger signal. The practice of using purple or other lights is highly dangerous.

7. Facing points ought to be avoided as far as possible. All facing points, and points leading to main lines, ought to be provided with a locking bar and bolt, and properly interlocked with the signals and with the electric apparatus.

8. At all junctions not only should the levers be locked in the box, but an actual lock should be placed upon the arm itself at the top of the signal post; and in every case where electric repeaters are used they

should work from the *arm itself*, not from the rod in the usual way.

9. All passenger trains ought to be provided with an efficient automatic continuous brake, having brake blocks upon the wheels of the engine, tender, and every vehicle throughout the train, and fulfilling the five conditions laid down by the Board of Trade, August 30th, 1877, and highly approved by the Society. To avoid the present dangerous practice of brake power being cut off and rendered useless by the introduction of an unfitted vehicle, it ought to be the law that one company shall not be allowed to send vehicles over the line of another company unless such said vehicle is provided with the same form of continuous brake as that used by such foreign company.

10. All goods engines should be fitted with brakes upon their wheels, and those occasionally required for passenger traffic should have continuous brakes. On lines having heavy inclines, goods and mineral trains should have two guard's vans and two guards.

11. Tank engines should not run with the coal bunker in front; they should be turned, like a tender engine, and always run chimney first. Tank engines should never be run at express speed, as they are unsafe at such speed.

12. All passenger trains should be fitted with efficient means of communication with the driver and guards. Passengers should be able to reach it without putting their hands outside the window. The present cord system is unreliable, and the plan of having no communication on trains which stop every twenty miles is very risky to the public.

13. All passenger platforms should be raised to the

standard height, and all carriages fitted with a high continuous footboard, to avoid persons falling between platforms and trains.

14. The crank or driving axles of locomotive engines should be taken out after they have run a certain mileage. What the mileage limit should be ought to be at once decided by the companies and the Board of Trade. The Society considers 200,000 miles for iron, and 180,000 miles for steel, a very reasonable and safe suggestion for full consideration.

15. All tyres should be fastened to their wheels, so that if they break they cannot fly off.

16. All curves of ten chains radius and under should be provided with check rails.

17. At all important junctions, to avoid the up main line being crossed by the down branch, or *vice versâ*, it is very advisable that the branch line be carried over a bridge and brought down to the main line level, as done at Finsbury Park and a few other junctions.

18. All waggons should be fitted with a coupling, so that waggons could be coupled or uncoupled without a man having to go between the vehicles.

19. Overwork on railways is highly dangerous, and ought to be abolished. Ten hours a day is plenty, and proper time for rest ought to be allowed between each term of duty. Eight hours of signal-box work, considering its importance, should be enough; and at very large and busy junctions six hours at a stretch is as much as should be required.

20. Companies' rule-books should be revised, and all rules not intended to be carried out should be removed.

21. Unpunctuality of trains is a great cause of accidents. When an important passenger train is running

late the working time-table is rendered useless, as none of the trains booked to shunt at various sidings do so, but proceed to some other siding, and are therefore unable to work as booked. When it is found, day after day, that certain trains do not keep time, the time-table should be properly altered in accordance with the actual running or time necessary.

22. In case of fogs great care ought to be taken that the fog signalmen are sent out early enough; but it is to be hoped that at no very distant date one of the various mechanical appliances will be adopted in place of fogmen.

23. All inclines should be provided with "catch points" to prevent vehicles running away.

CHAPTER II.

PERMANENT WAY, ANCIENT AND MODERN.

There seems to be a widespread impression that railways came suddenly into existence as a complete system at the time when the Liverpool and Manchester Railway was opened in 1830, and little or no attention is paid to previous history, or to the reasons which led, step by step, to the various improvements and inventions.

The railways of the present day owe their existence to, and are the practical result of, the wonderful development of the ancient tramways or railroads. The discovery that a horse could draw a much greater load upon a hard level surface than upon an ordinary road led to the introduction of "stone tracks," which consisted of long narrow flagstones placed in parallel lines, upon which the cart-wheels ran.

About the year 1630, it appears a Mr. Beaumont went to Newcastle-upon-Tyne, and to facilitate the conveyance of coal from the collieries to the docks or shipping places, he introduced the "wooden way," consisting of cross sleepers placed about 2 feet apart, upon which were nailed wooden planks 6 feet long and about 4 inches wide. He likewise introduced four-wheeled waggons in place of the ordinary carts; and in "The Life of Lord Keeper North" it is mentioned that "the carriage is so easy that one horse will draw

down four or five cauldrons of coal, and is an immense benefit to the coal merchants." A book published by Mr. Gray in 1649 records the fact that Mr. Beaumont in a few years lost £30,000, which he "adventured in the mines."

The waggon wheels in course of time wore away the upper surface of the wooden ways, and the next fact on record is, that instead of entirely replacing the old ones, new planks were nailed upon them. This plan was known as the "double way." It was again followed by the system of "plating" the wooden tracks with sheet iron, or by nailing iron plates or bars upon them. These became known as "plateways," and the men employed to lay them down as "platelayers." It is hardly necessary to point out that this latter word remains in use to this day, but the difference between the "plates" of old and the present steel rails, 30 feet long, weighing 85 lbs. per yard, is indeed striking.

The iron-plated ways, as might be expected, very soon caused considerable wear to the wooden wheels, and about the year 1753 it appears that cast-iron wheels were introduced.

In 1767, Mr. Reynolds, one of the partners in the Colebrookdale Iron Works, Shropshire, suggested that the wooden plated ways should be entirely superseded by a cast-iron rail or plate, and that, in addition, an upright ledge or flange should be cast upon it, for the purpose of keeping the wheels upon the line. These rails were 3 feet long, 4 inches wide, having a "fish-backed" flange on the inner side, 3 inches high at middle, and 2½ inches at the ends, fastened to wooden cross sleepers by a nail or spike driven through a hole, formed by a small square

piece being left out in each end of the castings. From the books of the Colebrookdale Company it appears that on the 13th November, 1767, between five and six tons of rails were cast, and at once laid down as an experiment. At first, it seems, they were not successful, being frequently broken, and in the following year (1768) the waggons were considered too large and heavy. These were, therefore, replaced by a number of smaller ones coupled together, thus reducing the weight upon any one rail, and distributing it over several yards of the way. To give additional strength to the plate rails, an improvement was made, consisting of a "fish-bellied" flange projecting downwards under the plate.

In 1776 a somewhat similar cast-iron plate way was laid down by Mr. John Curr, at the Duke of Norfolk's Colliery, near Sheffield; the rails were 6 feet in length, the ledge or flange was 2 inches in height throughout, and was placed on the outer side of the track. Cross sleepers were employed under the rail joints. The two intermediate supports to each rail consisted of square wooden blocks, near each end of each plate, and at intervals of two feet, holes were cast for a nail to be driven into the sleeper or block. It has been claimed that Mr. Curr was the first to lay down the cast-iron way, but the date at once shows that such a claim is an error, as the Colebrookdale experimental line had been at work for nine years. It appears that the labouring people at the colliery did not understand the great future of the iron way, for they got up a riot, tore up and broke the rails and burned the sleepers.

One of the greatest improvements was introduced (1789) by Mr. William Jessop, when constructing a railroad at Loughborough, in Leicestershire. This

engineer decided to abandon the flat wheels and flanged rails and to introduce iron rails with a flat top, and wheels with a flange cast upon the tyre. Mr. Jessop's rail was known as the "edge rail," because the wheels ran upon the upper edge. These rails were of cast-iron, 3 feet long, having a single head 1¾ inches wide; they were of the elliptical, or "fish-belly," pattern, that is, deeper in the centre than at the ends, it being considered that it combined the greatest strength with the least expenditure of material; the gauge of this line was similar to that adopted for the plate ways, namely, 5 feet outside. The rails were fastened to cross sleepers by iron pins or bolts passing through projecting bases cast at the end of the rails. It was soon found that the cast-iron projections were broken off, and the rails rendered useless, as there was no way of fastening them; this led to a great and important improvement. The base was removed from the rail itself, and cast as a separate "chair" or "pedestal;" the rails were fastened by pins passing through holes in the upright sides of the chairs, and corresponding holes in the ends of the rails.

In 1797, Mr. Barns, when laying down a railroad at the Lawson Colliery, Newcastle-upon-Tyne, introduced "stone blocks" 1 foot square and 8 inches deep, instead of wooden sleepers, and in 1800 Mr. Outram also used "stone blocks" upon a line he laid from the collieries near Little Eaton, Derbyshire. The dates plainly show that Mr. Outram was not the first to adopt the "stone blocks," but, nevertheless, he obtained all the credit, for this description of line was called the Outram road or way, which very soon became shortened into "tram-road" and "tramway."

The Ashby Canal Company, under an Act of 1794, constructed a canal from Ashby-de-la-Zouch (Leicestershire) to Coventry, and obtained powers to extend it to Ticknall and Cloud Hill Lime Works, &c., but the directors, seeing the advantages of the "tram-road," abandoned the latter part of their canal scheme, and laid the Ashby, Ticknall, and Cloud Hill tramways, the rails employed being the cast-iron "plate" pattern, 3 feet long, with the flange on the inner side, similar to those originally introduced at Colebrookdale, to which reference has already been made. The old Ashby tramroad and branches became the property of the Midland Railway Company, by virtue of an Act of 1846, and one part has since been altered and absorbed into the Ashby and Worthington Railway, but the branch from Ticknall Tramway Wharf to Ticknall has never been relayed or altered in any way, and is therefore a specially interesting relic of ancient times. In these days to see waggons with flat wheels, drawn over cast-iron plate rails one yard in length, by a horse, cannot fail to interest those who watch the progress and working of railways; and it most clearly shows the great improvements made, and the perseverance which has been required to develop the present gigantic railway system out of such small beginnings.

In 1801 the Surrey Iron Railway Company obtained an Act, and afterwards speedily constructed a tramroad from Wandsworth to Croydon; and Sir Richard Phillips wrote: "I found delight in witnessing, at Wandsworth, the economy of horse labour of the iron railway, and thought such lines should be extended from London to Edinburgh, Glasgow, Holyhead, Milford, Falmouth, Yarmouth, Dover, and Portsmouth." The idea that

railways should be laid over the country was generally considered at that time to be perfectly absurd.

An important tramroad six miles in length was also laid in Derbyshire, known as the Peak Forest line. Wrought-iron rails 2 feet long were tried in 1805 at the Wallbottle Colliery, near Newcastle-upon-Tyne, but this material did not come into general use.

In 1816 a patent (No. 4,067) was obtained by William Losh and George Stephenson for a half-lap rail-joint, in which the sides of the rails were bevelled away for about 2½ inches, so that when the two bevelled ends were laid, they formed the same breadth of surface as at the other parts of the rail, an iron pin passed through the sides of the chair and the halves of the two rail ends; they also suggested a wheel with a broad flat flange, suitable to run upon either the plate or edge rails.

It has already been mentioned that the "edge rail" was invented in 1789; it did not, however, find favour for a number of years, as many persons contended that the narrowness of the upper surface would cut grooves in the wheels, a preference being therefore shown for the old plate-rail.

A very useful wrought-iron rail was next manufactured at the Bedlington Iron Works in 1816, which consisted of a combination of both the plate and edge rails, and having a high outer side and a low one; wheels with flanges ran upon the high or edge side, the flat wheels on the inner or low-plate side. These rails were in 15 feet lengths, the ends being dove-tailed together; they were sometimes spiked directly to the stone blocks, but more generally placed in shallow chairs, and secured with an iron key.

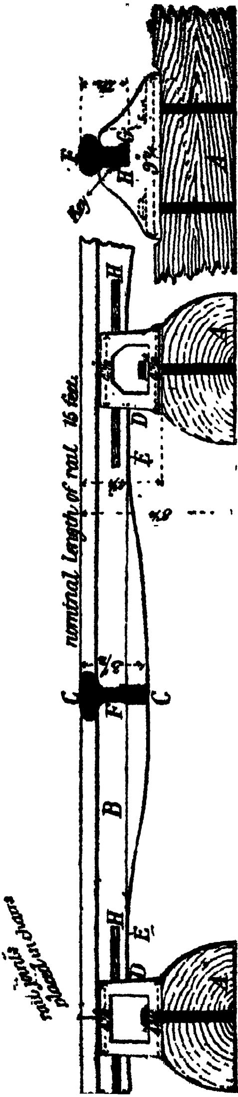


Fig. 1.—Fish-bellied Rail.

In October, 1820, Mr. Birkinshaw, of the Bedlington Iron Works, near Durham, obtained a patent (No. 4,503) for an improved mode of rolling railway rails (Fig. 1).

These rails were of wrought iron, of the elliptical, or more generally known as the "fish-bellied" pattern, nominally 15 feet in length, but from measurement the author finds them to vary from $\frac{1}{2}$ inch to $1\frac{3}{4}$ inches more than this length. They were divided into bearing lengths of 3 feet between the chairs, and, when new, weighed 28 lbs. per yard; they had a single head only, $2\frac{1}{4}$ inches in width. The peculiar feature was that the underside of the rail was curved. It was considered in the early days of railways that extra strength was required between the chairs (at c), and that it would give uniform strength throughout if the extreme depth of the

rail at the centre between the chairs was $3\frac{1}{4}$ inches, tapering away in a semi-elliptic curve to $2\frac{1}{4}$ inches at the chairs (D).

On one side of the rail a lateral swell was rolled, and continued through the whole length; but on the other side it terminated at E before reaching the chair, thus forming the sections shown at F. The chairs were of cast iron; on one side a cavity (G) was formed corresponding to the lateral projection on the rail, on the other side of the chair a similar cavity was cast for the purpose of receiving a long thin wrought-iron key (H), which pressed the projection on the rail into the cavity in the chair (G), thus preventing the rail from rising upwards.

Mr. Birkinshaw proposed to weld a number of rails into a long continuous rail, but this plan was not tried. Mr. George Stephenson adopted Birkinshaw's "fish-bellied" rail for all his early lines. The Stockton and Darlington, Canterbury and Whitstable, and Leicester and Swannington had rails weighing 28 lbs. per yard; on the Liverpool and Manchester he used 35 lbs., and afterwards 50 lbs. on the London and Birmingham.

On the Liverpool and Manchester line both stone blocks and wooden sleepers were employed. The Leicester and Swannington Railway was laid with cross sleepers (A), placed 3 feet apart between centres; these were of oak, 8 ft. 6 in. in length, $8\frac{1}{2}$ in. wide at base, $4\frac{1}{4}$ in. thick, of half-round section, bound at each end with a strong iron hoop, the chairs being fastened to them by two spikes.

The "gauge of rails" may here receive attention, as the question has been asked why 4 ft. $8\frac{1}{2}$ in. was adopted.

There can be no doubt that the usual width of the old

wooden and cast-iron tramroads practically determined the gauge of our present railways. The usual width or gauge of these old tramroads was *five feet* over all, that is, including the width of the two rails, and, as Jessop's edge rails and the Killingworth tramroad had rails $1\frac{3}{4}$ inches wide, it is easy to see that the width of two such rails deducted from 5 feet leaves 4 feet $8\frac{1}{2}$ in. between the rails, or what we now consider the national gauge. George Stephenson saw no reason to alter the gauge, therefore he adopted 4 ft. $8\frac{1}{2}$ in. for the Stockton and Darlington and the Liverpool and Manchester railways, and, when consulted as to the gauge for the Leicester and Swannington, and the Canterbury and Whitstable Railways, he replied, "Make them of the same width; though they may be a long way apart now, depend upon it they will be joined together some day." The "fish-belly" rails, 15 feet long, were adopted for all these lines.

The Stockton and Darlington railway scheme was one of the important turning points in the railway history. George Stephenson was appointed engineer, and application was made to Parliament in 1818; twice the Bill was rejected, but it passed in 1821, and on the 27th of September, 1825, the line was opened. It was not at first intended to work this railway by locomotives, and some fixed engines and ropes were provided, but the locomotive quickly proved its superiority over all other systems.

The Liverpool and Manchester has been truly designated as the Grand British Experimental Railway. George Stephenson was in this case also appointed engineer, and the line was opened to the public 15th September, 1830. Some time before the opening, the

question of locomotive, or fixed engines and ropes, naturally came before the directors, as it was necessary to arrange for working the line; and, notwithstanding reports, the directors did not feel able to come to a decision, when one of their number—Mr. Harrison—proposed, "That a reward be publicly offered for the most likely mode of effecting their object;" and on the 20th April, 1829, it was resolved to offer a premium of £500 for the best locomotive engine, subject to eight conditions as to weight, load, pressure of steam, price, &c., and the offer was made on the 25th April.

October 1st, 1829, was fixed for the trial, but was subsequently altered to the 8th, the running ground being on the Manchester side of Rainhill Bridge; and the following engines were entered for the prize:—

Engine	Maker
The Rocket	.. G. Stephenson.
The Novelty	. Braithwaite and Erickson
The Sans Pareil	Hackworth
The Perseverance	Burstall

The result of the trial (which lasted from the 8th to 14th October) conclusively proved that the "Rocket" of Mr. Stephenson was the best engine, and the price of £500 was consequently awarded, as it had performed all the conditions and stipulations required by the company. It will thus be seen that the Rainhill trials of 1829 settled the locomotive question, and led to the introduction of railways throughout the world.

It has been mentioned that the "elliptical" rail was adopted with a view to obtaining uniform strength throughout its length; experience, however, proved that this was not the case in practice, as all the rails which broke failed at a point between 7 in. and 9 in. from the nearest chair. It was also shown that

after one side of the top was worn, the rail could not be used on the other without the chairs being taken up and turned round; also that it was very inconvenient in practice that chairs could only be placed at certain points—that is, at the shallow parts of the rails.

To avoid these defects a rail was designed having a single head, but the under side was made straight and parallel to the top: this was known as the "single parallel pattern." These rails were 15 ft. in length, and were secured to the chairs by a ball and key fastening; a groove was rolled in one side of the rail into which a small cast-iron ball fitted, this ball being in turn held firm by a wrought-iron key passing through the chair. This system of rail and fastening was largely used on the North Midland, Manchester and Leeds, Birmingham and Derby Junction, and many other lines. Mr. Locke adopted the "double parallel rails," and laid them down on the Grand Junction Railway. These had double heads, and were therefore capable of being turned; they were placed in chairs 3 ft. apart, and secured by wooden keys. From this description it will at once be seen that Mr. Locke's system is the one in general use at the present day.

Great difference of opinion existed as to the merits of the various forms of rails. The directors of the London and Birmingham Railway, being in doubt, employed Professor Barlow to conduct a series of experiments. He did so, and reported in favour of Locke's "double parallel," and against Birkinshaw's "fish-bellied" rail, and this report led to the very general adoption of the former system.

Soon after the opening of the Leicester and Swan-

nington Railway, which took place 17th July, 1832, opinions were expressed against wooden sleepers, especially in cuttings. It therefore became the fashion to adopt "stone blocks," and, to consolidate the road-bed, it was the general practice to lift each block by means of a lever, and allow it to fall several times on the seat upon which it was intended ultimately to rest. This method of obtaining a firm road was first employed by Mr. Stephenson on the Liverpool and Manchester line.

Nothing can be worse than a rigid permanent way, but in the early days of railways this fact was not known or understood, consequently very many ideas and inventions proved failures. They provided a very strong road, but the rigidity was so great that the permanent way and rolling-stock were jarred to pieces, not worn out by ordinary working, thus clearly showing that a certain amount of "elasticity" was absolutely necessary. When Mr. Brunel originally designed the permanent way for the Great Western Railway, a peculiar feature was introduced (in addition to the broad 7 ft. gauge and the longitudinal sleepers), which consisted in the employment of piles driven in pairs along the whole length of the way, at intervals of 15 ft.; these piles were of beech, 10 in. diameter, 12 ft. long, driven down into the earth so that the top of each was nearly level with the rails, and to the tops of these piles the cross timbers were firmly bolted, which in turn held the longitudinal sleepers. This plan was carried out in 1838–9 between London and Maidenhead, but the results very quickly induced Mr. Brunel to abandon the piles and lay the timbers on the ballast in the ordinary way.

Practical working soon proved that the "pile"

system was nearly as rigid as the "stone block road," and when the ballast subsided, as it constantly did, the whole weight was placed upon the piles.

Another attempt to obtain a firm permanent way was made upon the Manchester and Leeds Railway in 1839. One part of the line passed for some distance through a rock cutting, and, instead of using sleepers, the solid rock was dressed to a surface, and the chairs spiked directly to it. The company's officials contended, and expected that this portion of line would stand firm for ever. However, the road was so rigid that if a train passed over it at more than a walking pace, rails and springs were broken, and in less than three weeks from the opening of the railway orders were given for the rails to be taken up and placed upon sleepers in the ordinary way.

Mr. Jesse Hartley constructed some parallel walls of granite, upon which he bolted the rails. The rigidity was so excessive that rails, tyres, and springs were broken daily, and the plan proved a complete failure.

A report contained in the Leicester and Swannington Company's books, dated May, 1842, shows that the "stone blocks" which had replaced many of the sleepers required constant attention, lifting, packing, and keeping to gauge, also that "the riding over them was harder than on the oak sleepers."

However, "stone blocks" remained in use on many lines for a period of over forty years, and some even exist in sidings and branches at the present day in various parts of the country.

During the years 1847–51 great attention was given to the subject of iron permanent way, it being the general opinion at that time that wooden sleepers

were of too perishable a nature. Many inventions were tried. The one which appears to have been most successful was W. H. Barlow's patent. This system had cast-iron sleepers placed longitudinally. Each sleeper consisted of an inverted trough 4 ft. 8½ in. long, 1 ft. 1½ in. wide, and 3 in. in height, with the chairs upon it, cast in one piece, the wooden keys being placed inside; the rails were of iron, 18 ft. long, double-headed, and fished at the joints; the gauge of the line was maintained by a wrought-iron transverse tie-bar attached to the sleepers. This "iron road" was tried upon several sections of the Midland Railway, especially through tunnels. The first portion laid was slightly over a mile in length, and extended through the Glenfield Tunnel on the Leicester and Swannington branch, the next being the Thackley Tunnel, Shipley, followed by the Gresley Tunnel, near Burton, and many others. Experience quickly proved that this system was too hard and rigid, and, as the weight of engines gradually increased, the cast-iron sleepers were constantly broken. For a number of years past the Glenfield Tunnel has been the only remaining portion of the iron road in use, and on this account the mouth of this tunnel has been constantly visited by engineers and others who wished to examine these old links in the history of permanent way; but in March, 1884, the removal of the cast-iron road was completed, after having been in traffic over thirty-two years.

The Barlow "Saddle-back" wrought-iron rail was designed to dispense with sleepers and chairs altogether, the foot of the rail being considered wide enough to obtain the necessary bearing surface upon the ballast, the gauge being maintained by wrought-iron tie-rods.

The fatal objection to all rails of this type was found to be their rigidity, and the great disadvantage of the impossibility of properly packing them.

One of the first requisites for a railway is a good, sound permanent way, placed upon a well-drained and properly ballasted road-bed. This is a subject of very great importance, and deserves far more attention than is sometimes bestowed upon it, for there can be no doubt that good ballast is to a railway what a good foundation is to a building; defective drainage and ballast often cause subsidence and lateral deviation, increase the cost of maintenance both of road and rolling-stock, and, what is far more serious, will probably render the line unsafe and lead to an accident.

It may often be noticed on badly-drained railways that water lies under the sleepers, and that when a train passes, mud is thrown up as each sleeper in succession sinks under the pressure of every wheel, the fish-joints bend and spring back, the rails rise and fall in the chairs with a clattering noise, the wooden keys shake and often fall out; thus the permanent way is strained, and consequently the trains oscillate considerably. Having obtained a good dry road-bed, it is necessary to consider the requirements of the permanent way and the duties it has to fulfil. In the first place, it must be strong enough to carry the loads which pass over it, and also to resist the lateral action due to speed and oscillation, which tends to the "spreading" of the rails.

It must be specially remembered that when speaking of the load on the permanent way the author does not refer simply to the total weight of the engine or vehicle, but to the maximum weight which is or can be placed upon it at any one point; that is, upon any one pair of

wheels. Therefore a heavy engine of 38 or 40 tons, having the weight well distributed over six or eight wheels, will not cause as much wear and tear or damage to the permanent way as a comparatively light engine with a great weight placed on one pair of wheels. Many locomotive engines are in use in this country having 16, 17, and nearly 18 tons resting upon a single pair of driving-wheels; and it is this great concentration of weight which forms the principal difficulty which permanent-way engineers have to overcome.

Rails may be considered as girders; they must have strength enough to carry the load which rolls over them, and sufficient bearing upon the chairs; the chairs must have a good bearing to prevent their being crushed down into the sleepers, and in like manner the sleepers must have surface enough to prevent their being crushed into the ballast; the spikes and tree-nails must resist all lateral action and maintain the gauge of the line. Permanent way, therefore, must be strong and firm, but at the same time possessing a certain amount of elasticity; it is very necessary that the elasticity should be uniform throughout, and not a system of alternate elasticity and rigidity, in which it serves to aggravate the rigidity by causing a succession of jumps and jerks.

Previously to the year 1847 rail-joints were placed over sleepers in joint-chairs, which were wider than the ordinary ones. The joint thus made was never satisfactory, and upon several occasions the keys fell out of the joint-chairs, and trains or vehicles left the line in consequence. The well-known "fish-plates" were introduced by Mr. Bridges Adams in 1847, and it is hardly necessary to point out that they are very successful, and are now in universal use.

About the year 1847 great difference of opinion existed as to the advantages of the "suspended fish-joint," and of the "joint supported by a sleeper." Engineers had become so used to the supports placed under the joints that great objections were raised to fish-plates and joints suspended between two sleepers, and several inventions were tried with a view to obtain a compromise. Mr. Samuel introduced a bracket-chair, which was largely used. It consisted of a chair and fish-plate combined, the fish on one side being cast with the chair and an ordinary fish-plate placed on the other side, four bolts being employed in the ordinary way. A somewhat similar chair and fish-plate combined was afterwards introduced by Mr. Adams, who also designed a modification of the joint-chair and fish-plate capable of uniting the ends of rails of different heights and sections, but they have given place to the usual fish-joint.

There can be no question that the suspended fish-joint gives greater elasticity, and renders the deflection of every part of the permanent way as uniform as possible under the weight of a passing train. The author has for a long time directed the attention of permanent-way engineers to a matter which on many railways requires improvement, namely, the positions of sleepers on each side of a rail-joint. To obtain a good sound road a chair and sleeper should be placed on each side of a joint as near as possible to the fish-plates; from the joints of the rails to the centre of the nearest chair on either side should never be more than 12 or 13 inches. Doubtless many of my readers often see sleepers brought close up to the joint on one side, whilst the centre of the next sleeper may be 2 feet or 2 feet 6 inches on the

other side. This is a common, but at the same time an objectionable practice. To obtain a smooth road uniformity of elasticity and deflection is very necessary, for if the deflection be not equal throughout, pitching motion is at once created, followed by violent oscillation, which is detrimental to the permanent way itself and injurious to the locomotives and rolling-stock. It has already been mentioned that the system of fastening rails by wooden keys was originally introduced by Mr. Locke upon the Grand Junction Railway; Mr. Barlow afterwards invented a hollow wrought-iron key of a similar shape to the usual wooden one; those were tried for a short time, but their use proved that elasticity in keys was absolutely necessary.

A large number of other systems were tried, and proved failures solely on account of their extreme rigidity. The position of rail-keys has recently engaged considerable attention, in consequence of the change made by the Midland Railway Company.

On the majority of lines the keys have always been placed *outside* the rails, and previously to the year 1850 this was the usual plan; at that time, and during the ten following years, the Midland Company employed both the "outside" and "inside" systems, and found that the keys placed "outside" came out of the chairs to a serious extent; on some occasions three and even four consecutive keys were found to be out, the result being that there was nothing to prevent the train from "spreading the road" to a dangerous extent, and cases did actually occur of vehicles leaving the line in consequence. The company therefore, in 1860-1, considered that the *inside* position was to be preferred, as if the keys should come out there would be no danger, the

gauge of the line being maintained by the outer jaw of the chair, and not by the key. It was also considered that platelayers would more conveniently examine their lengths of permanent way when they could see the keys of both rails at one time.

The inside keys gave general satisfaction for several years, and there was no doubt that the system made a good strong road; the question is whether it was not too strong, amounting to rigidity, for since the weight of engines and rolling-stock has increased, the number of broken chairs has become a very serious matter for consideration and attention.

Complaints have for a long time been made that Midland trains appear to run "harder" and more "noisily" than those of some other lines.

One cause of "noise" is doubtless to be found in the inside keys, and another in the low system of ballasting. The recent decision of the Midland Company to adopt outside instead of inside keying has called attention to the whole question of permanent way, and promoted considerable discussion in engineering circles. The advocates of the inside and outside systems appear to have been very equally divided, and powerful arguments have been brought forward upon each side; but it must be admitted that the introduction of wood between the rail and chair will provide the necessary elasticity which is so evidently required to prevent the continual breakage of chairs.

Experiments are being made to obtain some really good system of preventing keys working out of the chairs. Several plans are being practically tested upon parts of road with the heaviest traffic. Good results have been attained by the use of the chairs

which are roughed or have teeth on the inner side of the jaw.

Another form of key has been introduced by Mr. Gradwell, of Barrow-in-Furness. It is of wood, shaped so that it can only be driven into, or come out of, the chair in one direction. A piece is sawn out, or four saw cuts made. To drive a key into its place, the end is compressed, and afterwards expands, practically forming a spring which prevents its falling out. With a view to giving additional elasticity to the road, the "Steen Chair and Spring Key" has recently been tried experimentally, and consists of a strong curved spring key, formed in the centre to fit the chair, the ends pressing against the rail, and in order to prevent the ordinary wooden keys falling out, some are now being tried with an improved means of fastening, which consists in cutting a groove or saw cut in the key to receive an iron or steel wedge having serrations or teeth on each side to prevent slipping back.

It will be noticed upon many railways that the sleepers and the undersides of the rails are covered with ballast. This tends very materially to insure quiet running; but, on the other hand, in rainy seasons it keeps the permanent way in a wet state, unless very well drained. The Midland Company adopted the plan of never allowing the ballast to cover the sleepers, thus insuring a dry road, but at the same time a noisy one. This plan is now abandoned, and the ballast is being raised upon all relaid portions of the line, which, together with the outside keys, has had the desired effect of reducing noise and vibration. In shunting-yards and sidings the ballast should always be raised (both between the rails and in the six-foot

way) to the level of, or very little below, the top of the rail. Many guards and shunters are annually killed and injured by catching their feet against the tops of the rails when stepping under the buffers of waggons, either to couple or uncouple them, and, of course, any slip made at such a critical moment is almost certain to result in serious consequences; and, as the raising of the ballast to the required level in shunting-yards is such a very simple and inexpensive matter, it is to be hoped the companies will do all in their power to reduce the danger as far as possible. At the present time permanent way may be divided into two classes:—

1. The cross sleeper road in general use.
2. The longitudinal system used on the Great Western Railway.

Rails may be considered under four classes:—

1. Single or bull-headed.
2. Double-headed.
3. Bridge pattern.
4. Vignole's pattern.

Various companies make differences in detail, but the Midland may be selected as a fair example of the ordinary 4 feet 8½ inches gauge, cross-sleeper road, as follows:—The rails are of steel, "bull-headed," 30 feet long, 5⅝ inches deep, width of top 2⅝ inches, weighing 85 l s. to the yard, having a sectional area of 8 square inches, and are laid with an inclination of 1 in 20 towards the inside, or four-foot way. The chairs are of cast iron, each weighing 50 lbs., and are fastened to the sleepers by two iron spikes and two oak tree-nails. The sleepers are rectangular, 9 feet long, 10 inches wide, 5 inches thick, weighing 134 lbs. each, and placed at a distance of 2 feet 9⅜ inches apart

between centres, except at the joints, where they are only 2 feet 2 inches apart. The fish-plates are upon the clip pattern—that is, they clip the rail by nearly meeting under it. They weigh 40 lbs. per pair, and the four bolts 1·68 lbs. each. To obtain correct data, the materials have been carefully weighed, and it is found that one yard of permanent way averages—

	Lbs.
Steel	170
Wrought iron	14·9
Cast iron	110
Wood	151.9
Total	446·8

Double-headed rails, capable of being turned, are in use on many railways; the general details of road are, however, very similar to the above.

"Turned" rails should never be used on any passenger line, both on account of the jar caused by running over the chair-marks, and also the increased liability of a rail to break when turned. The longitudinal system of sleepers was employed by Mr. Brunel for the broad gauge Great Western Railway, and was afterwards adopted in all cases where the seven-feet gauge was laid. The longitudinal timbers or baulks are of yellow pine, creosoted; they are rectangular, 14 inches wide, 7 inches thick, varying in length from 25 to 35 feet, and weighing about 40 lbs. per cubic foot; the gauge is maintained by transoms secured to the longitudinals by tie-bolts or iron-straps. The rails are of steel, of the "bridge pattern," varying in length from 18 to 30 feet, and in weight from 62 to 68 lbs. per yard. The 68 lbs. rails have a sectional area of 7 square inches, and are 6¼ inches wide at the foot,

and 3 inches high; they have a continuous bearing on the longitudinal timbers, to which they are fastened by fang-bolts passing through holes in the flanges. It has been found that the rails are in time pressed into the timbers, and, to avoid injury to the latter, packing 1 inch thick of yellow pine is generally placed under the rails. On a large portion of this line, the "mixed gauge" is now laid, which consists of a third rail to be used by narrow gauge trains, one of the broad gauge rails being common to both. The Vignole's system is only employed to a limited extent, and consists of a single-headed rail with a flat foot. It is used either with or without chairs, on either cross or longitudinal sleepers. During the year 1885, 287 broken rails were reported; of these 132 were double-headed, 145 single or bull-headed, and 9 were of the bridge pattern, and 1 Vignole's pattern. Of the double-headed rails, 68 had been turned, 54 rails were made of iron, and 233 of steel.

The old system of slide points has long ago become extinct upon all railways, but may still be seen in use on temporary lines and colliery sidings. By this arrangement a single pair of rails was fastened at one end by bolts, the other ends being capable of being moved sideways, so as to connect with two, three, or even four lines of way. The present form of points consists of two outer or fixed stock rails, and two inner or movable switch rails, tapered to a point or tongue. These point rails are fixed at the heel-end by either a pair of fish-plates or a heel-chair. Points, although of one construction, are known under various names, according to the position in which they are employed. Facing, trailing, slip, double slip, leading, cross-over,

safety and catch points, the names clearly indicating their several uses. Facing points at junctions, and leading points from goods lines or sidings to main passenger lines, should always be provided with locking bars and bolts, and be properly interlocked with the signals giving permission for a train to run in any desired direction. Crossings are of two kinds, the ordinary rails cut and joined, and cast-steel crossings complete in one piece. Crossings deserve far more attention than they sometimes receive, for if check-rails are allowed to become loose, and crossings to get out of position, it is a very easy matter for the leading wheel of an engine to strike and mount the fixed point of the crossing, thus throwing a train off the line, as was the case at Wennington Junction on the Midland Railway, 11th August, 1880, when eight persons were killed, and a very large number seriously injured. There is a common but very dangerous practice in use on some lines, of laying rails round curves tight to gauge, that is at a less width than 4 feet $8\frac{1}{2}$ inches. Many accidents have been thus caused, and the author finds that nothing conduces to easy and safe running on curves so much as a little extra width in the gauge. All sharp curves of ten chains radius and under should be provided with a check-rail placed round the inner side; the outer rail should be sufficiently super-elevated, and the speed of trains carefully reduced and regulated. Engines having a long rigid wheel base ought not to be employed on lines having sharp curves. The super-elevation of the outer rail is usually determined by the following formula: $W \frac{V^2}{1{\cdot}25\ R} =$ elevation of outer rail in inches. Where $W =$ gauge in feet, $V =$

velocity of train in miles per hour, and R = radius of curve in feet.

In concluding this chapter, reference should be made to the steel permanent way, designed by Mr. F. W. Webb as a substitute for the usual system of wooden sleepers and cast-iron chairs. The sleepers are by preference of the ordinary trough section, and the chairs are riveted to them. The chairs, which form the chief feature of the design, are made from the crop ends of steel rails. These are first rolled into flat bars, and then cut and stamped into shape with a bulge in the middle of their width, so as to give strength to the jaws, and also to form a recess into which the wooden key may expand, and so prevent it from working out. It will be noticed that each chair is made up of two angle brackets and a packing piece, which serves to keep the rail from injuring the sleeper. Another feature is the placing between the sleeper and the chair pieces of paper or canvas, dipped in tar or asphalte, to keep out any moisture and to prevent sliding or working between the chair and the packing, and the packing and the sleeper. It is claimed for the system that it seems to offer every advantage for economy and simplicity of manufacture; and there can be no question that if it were generally adopted the cost of production would be greatly reduced. It would also be essential, as far as possiblo, to introduce one standard form of sleeper, and one standard form of punching, so that companies wishing to adopt steel sleepers may go into the market for them, as they would for a piece of timber for the same purpose, and not have to ask the manufacturers to alter their rolls or their machinery for punching the holes for every small order required.

The experiments with this form of permanent way commenced in May, 1880, and the North-Western Company has now 32,174 of the sleepers in use, and it is reported that those laid down six years ago are giving good results. With regard to first cost, this system is stated to compare favourably with the cost of the ordinary plan. A hollow steel spring key has also been tried by Mr. Webb. There can be no question that Mr. Webb's steel permanent way forms a very strong and sound road, but the subject of its rigidity is an all-important matter for consideration. Opinions differ very widely, and in the absence of necessary data, it is essential that some experiments should be made upon the subject before a correct estimate can be arrived at with reference to the probable success of steel permanent way.

The author has recently examined the steel sleepers on several sections of the North Western, the mile of line near Kettering on the Midland, also the portion of the Team Valley Branch of the North Eastern Railway, and finds that the steel sleepers cost about twice as much as the wooden ones; but they will doubtless last a long time, and are costing less in maintenance.

CHAPTER III.

RAILWAY SIGNALLING.

THE latest official information with reference to the signalling of railways in the United Kingdom is to be found in the Board of Trade Returns upon the arrangements and systems of working on the 31st December, 1884, the details being given under two headings: (1) The interlocking and concentration of signal and point levers; (2) the systems upon which the lines are worked relating to the block system, &c.

Table No. 1 shows that the levers require "concentration" in 5,389 cases, and "interlocking" in 5,189 instances; also, that no less than 3,130 pairs of "safety points" are requisite. From table No. 2 it will be seen that the total length of line open for passenger traffic was 17,933½ miles, of which 13,832 miles were worked on the absolute block system. There are 366 miles of single railway upon which only one engine at one time, or two coupled together, are allowed: thus leaving a balance of 3,735 miles which are still worked upon inefficient principles, and requiring the introduction of the absolute block system.

INTERLOCKING OF SIGNALS.

Summary No. 1.

—	Number of cases in which any passenger line is connected with, or crossed on the level by				Number of cases in which the usual requirements of the Inspecting Officers of the Board of Trade have, or have not, been complied with in the following respects:—					
	Any other passenger line.	Any goods line.	Any siding.	Any cross-over road.	Concentration of signal and point levers.		Interlocking of signal and point levers.		Addition of safety points in case of goods lines and sidings.	
					Have	Have not	Have	Have not	Have	Have not
England and Wales	3,861	1,336	17,292	6,499	25,916	3,072	26,089	2,899	16,867	1,761
Scotland	729	213	3,102	991	3,797	1,238	3,763	1,272	2,628	687
Ireland	385	76	1,194	277	853	1,079	914	1,018	588	682
Total United Kingdom	4,975	1,625	21,588	7,767	30,566	5,389	30,766	5,189	20,083	3,130

THE ABSOLUTE BLOCK SYSTEM.

Summary No. 2.

—	Total Length of Railway Opened for Passenger Traffic.		Distance Worked on the Absolute Block System.	
	Double.	Single.	Double.	Single.
	Miles.	Miles.	Miles.	Miles.
England and Wales	8,541½	4,187¾	8,025½	3,170
Scotland	1,130	1,647½	1,067¾	1,113
Ireland	591¼	1,925½	141	314¾
United Kingdom	10,172¾	7,760¾	9,234¼	4,597¾
Total	17,933½		13,832	

The following table gives in detail the facts relating to the more important railways, from which it will be seen that some of the principal lines have made considerable progress:—

Railway.	Total Length of Line Open for Passenger Traffic.		Distance worked upon the Absolute Block System.	
	Double.	Single.	Double.	Single.
	Miles.	Miles.	Miles.	Miles.
Cheshire Lines	125	—	92	—
Furness	72	34	71	34
Great Eastern	494	473	494	208
Great Northern	570	169	556	91
Great Northern and Great Eastern Joint	111	5	111	5
Great Western	1,041	988	889	753
Lancashire and Yorkshire	423	17	423	9
London and North-Western	1,363	311	1,347	280
L. & N.-W. & G. W. Joint	111	27	111	16
London and South-Western	523	225	523	200
London, Brighton, and South Coast	339	118	339	118
London, Chatham, and Dover	167	10	167	10
Manchester, Sheffield, and Lincolnshire	266	3	185	—
Midland	988	278	951	215
North-Eastern	921	425	916	412
North Staffordshire	149	19	143	19
South-Eastern	333	37	333	37
Somerset and Dorset Joint	2	89	2	89
Taff Vale	52	12	6	1
Caledonian	426	354	421	203
Glasgow and South-Western	218	112	211	70
Great North of Scotland	23	275	23	269
Highland	6	408	6	408
North British	400	69	353	139
Great Northern of Ireland	136	371	3	14
Great Southern and Western	206	301	21	17
Midland Great Western	149	275	68	9

THE BLOCK SYSTEM DESCRIBED.

It is hardly necessary to mention that the object of the absolute block system is to maintain a certain interval of space between all trains, instead of the uncertain interval of time as formerly in use.

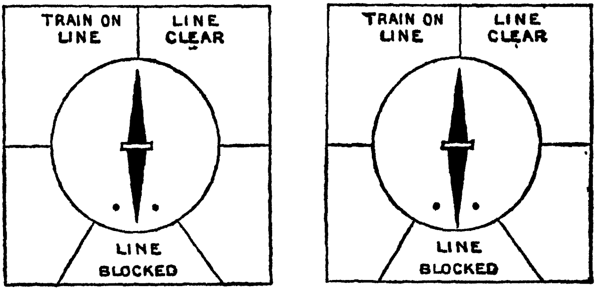
The line is divided into sections varying in length

from a few chains to four or five miles, according to the amount of traffic that has to be passed over it. A signal-box is placed at the termination of each section, and is provided with two electric bells and four block telegraph instruments, one bell and two instruments, Fig. 2, being for working the up and down traffic in each direction. Each signal-box is further provided with up and down "Distant," "Home," and "Starting" signals, and "Lie By" or shunting sidings are con-

Fig. 2.—THE BLOCK SYSTEM.

DIAGRAMS OF DIALS OF INSTRUMENTS (NEEDLE PATTERN).

UP LINE. DOWN LINE.



structed at such places as it is found necessary to allow a fast or important train to pass a slow train.

For the purpose of illustrating the course to be adopted in signalling by the block telegraph: A, B, C, and D, Fig. 3 (Plate I.) are supposed to represent four consecutive block boxes upon a portion of a double line of railway, and the process of signalling a train is as follows:—On the approach of a train to A, the signalman there will call the attention of B, and then give the proper "Is line clear?" bell and dial signals. The signalman at B, after having ascertained that the line is

clear for the train to run upon, must repeat the signals, and when he has received the necessary intimation from A that he has repeated the dial signal correctly, which intimation must not be given by A until the bell signal has also been correctly repeated, he must peg the needle to "Line clear." The train may then be dispatched from A. As soon as the train has passed A, the signalman there must call the attention of, and give the bell signal, "Train entering section," to B, and the signalman at B must acknowledge the signal and unpeg the needle. The signalman at A must then give to B the proper "Train entering section" dial signal, and when the signalman at B has acknowledged that signal and received the necessary intimation from A that his acknowledgment is correct, he must peg the needle to "Train on line," and then call the attention of, and give the "Is line clear?" signal to C. As soon as the train has passed B, it must be signalled, as above directed, to C and the signalman at C must in like manner, call the attention of, and forward the "Is line clear?" signals to D, and so on throughout the block system.

If the second train should arrive at a signal-box before the preceding one has been signalled as "Out of section," it must be brought to a stand and detained at the starting-signal until such time as the section ahead is clear.

For many years the codes of signals on different lines were separate and distinct, and at junctions there was the difficulty and danger of one man having to work two or more different codes. This was the cause of the serious accident at Canonbury Tunnel, and led to the companies parties to the Clearing House adopting a more uniform system, which came into use October to December, 1884. For the purposes of illustration,

the Midland, Great Northern, and Great Western signal codes are here appended :—

MIDLAND.

WHEN THE NEEDLE OF THE INSTRUMENT OF THE SECTION AHEAD IS IN THE VERTICAL POSITION THE LINE MUST BE CONSIDERED BLOCKED.

When the instruments are not in use, the handles must always be kept upright, so that the needles may stand in the vertical position. The needle and bell signals must be made slowly and distinctly, and the hand must be removed from the handle the moment the signal has been sent. The handles must not be touched, except when signals are being forwarded or acknowledged. Signalmen, on setting the needle to "Train on line," or "Line clear," must take care that it is firmly and completely pegged over.

Signal lights: red, stop; white, all right; green, all right at junctions.

The block instruments must not be used for conversing.

BELL SIGNALS.

To call attention	1 beat of the bell
Is line clear for stopping goods or mineral train, ballast train requiring to stop in section, or platelayers' lorry requiring to pass through tunnel?	3 beats ,,
Is line clear for passenger, break-down van, or empty carriage train?	4 ,, ,,
Is line clear for fish, meat, cattle, express goods, empty fish vehicle, through goods, mineral, or ballast train, or light engine? . . .	5 ,, ,,
Train entering section	2 ,, ,,
Obstruction danger signal	6 ,, ,,
Stop and examine train	7 ,, ,,
Signal given in error, train last signalled not coming	8 ,, ,,
Train passed without tail lamp (to post in advance)	9 ,, ,,
Train divided	10 ,, ,,
Shunt train for following train to pass . . .	11 ,, ,,

Train or vehicles running away on wrong line	12 beats of the bell
Section clear and station or junction blocked	13 ,, ,,
Train or vehicles running away on proper line	14 ,, ,,
Opening of signal post	15 ,, ,,
Testing bell signal	16 ,, ,,
Closing of signal post	17 ,, ,,
Time signal	18 ,, ,,
Lampman or fog-signalman required	19 ,, ,,
Testing controlled signals	20 ,, ,,

DIAL SIGNALS.

Signal correctly repeated	1 beat of needle to right
Is line clear for fast passenger train?	3 beats ,, ,,
Is line clear for slow passenger train?	4 ,, ,, ,,
Is line clear for express goods or cattle train?	5 ,, ,, ,,
Is line clear for through goods, mineral, or ballast train, or light engine?	6 ,, ,, ,,
Is line clear for stopping goods or mineral train?	7 ,, ,, ,,
Is line clear for ballast train requiring to stop in section, or platelayers' lorry requiring to pass through tunnel?	8 ,, ,, ,,
Testing dial signal	16 ,, ,, ,,
Signal incorrectly repeated	1 beat ,, left
Fast passenger train entering section	3 beats ,, ,,
Slow passenger train entering section	4 ,, ,, ,,
Express goods or cattle train entering section	5 ,, ,, ,,
Through goods, mineral, or ballast train, or light engine entering section	6 ,, ,, ,,
Stopping goods or mineral train entering section	7 ,, ,, ,,
Train passed without tail lamp (to post in rear)	9 ,, ,, ,,
Testing dial signal	16 ,, ,, ,,
Train out of section	2 ,, ,, right

Giving permission for a train to approach, and giving "Train out of section" signal.

Except where special instructions to the contrary are issued, permission must not be given for a train to approach when there is, within a quarter of a mile ahead of the home signal, any obstruction on the line on which such train requires to run, nor until all the points over which it has to pass have been placed in the proper position, and where block posts are not more

than a quarter of a mile apart, not until the "Train out of section" signal has been received from the post in advance for the previous train; and after permission has been given for a train to approach, no obstruction of the line upon which such train requires to run must be allowed within a quarter of a mile ahead of the home signal, and the points over which it has to pass must not be moved until it has passed, or been brought to a stand, or the signal, "Signal given in error, train last signalled not coming," has been received from the post in the rear.

GREAT NORTHERN.

Came into force at 1 P.M., December 1st, 1884.

BELL SIGNALS.

To call attention	1 beat on bell
Train on line	2 beats ,,
Be ready for goods, mineral, or ballast train stopping at intermediate stations	3 ,, ,,
,, ,, ,, passenger, special fish, or meat, running in passenger train time	4 ,, ,,
,, ,, ,, express goods, fish, cattle, light engine, or through mineral train, stopping at chief stations only	5 ,, ,,
Obstruction danger signal	6 ,, ,,
Stop and examine train	7 ,, ,,
Signal given in error (cancel signal last sent)	8 ,, ,,
Train passed without tail lamp	9 ,, ,,
Train divided	10 ,, ,,
Shunt train for following train to pass	11 ,, ,,
Vehicles running away on wrong line	12 ,, ,,
Section clear and station or junction blocked, to be used where authorised by General Manager or Superintendent of the Line	13 ,, ,,
Vehicles running away on right line	14 ,, ,,
Opening of signal box	15 ,, ,,
Testing	16 ,, ,,
Closing of signal box	17 ,, ,,
Time signal	18 ,, ,,

DIAL SIGNALS.

Signal correctly repeated	1 beat of needle to right
,, incorrectly ,,	1 ,, ,, left

Passenger, special fish, or meat train running in passenger train time	On line		2	beats of needle to left		
Express goods or cattle train .	,,	,,	3	,,	,,	,,
Express fish train or light engine	,,	,,	4	,,	,,	,,
Mineral or ballast train stopping at chief stations only . .	,,	,,	5	,,	,,	,,
Goods, mineral, or ballast train stopping at intermediate stations	,,	,,	6	,,	,,	,,
Stop and caution			7	,,	,,	,,
Passenger train assisted by engine, at rear	On line		9	,,	,,	,,
Goods, cattle, mineral, or ballast train assisted by engine at rear	,,	,,	11	,,	,,	,,
Train out of section			2	,,	,,	right
Line clear	Needle pegged to "Line clear"					

When the needle of the instrument is vertical, the line must be considered blocked.

The normal position of all fixed signals is "danger," and a green light is used by night at all the signal posts for "all right," and red one "danger;" a white light at a place where a red, or a green, or a purple light ought to be seen must be considered a "danger" signal, and treated accordingly.

"Call attention" must precede all bell and dial signals, and be repeated immediately.

TRAIN OUT OF SECTION.

CLAUSE 6.—"Train out of section" must, except during fog or falling snow, be sent as soon as the last vehicle, with tail lamp attached, has passed the signal-box. "Be ready" must not be accepted for a following train, nor must "Line clear" be given until the preceding train has passed at least a quarter of a mile beyond the signal-box and is continuing its journey or has been shunted clear of the main line (except under special instructions signed by the General Manager or Superintendent of the line, which will be placed in the boxes concerned).

GREAT WESTERN.

SPAGNOLETTI'S DISC BLOCK SYSTEM.—DOUBLE LINE.

Issued November, 1884.

	Beats on Bell.	How to be given.
*To call attention (for an unusual continuance of block, &c.)	1	1
Train on line	2	2 consecutively
,, arrived or obstruction removed	3	2 pause 1
Is line clear for ordinary goods, mineral, ballast train, or engine and brake?	3	3 consecutively
Is line clear for branch goods train	3	1 pause 2
,, ,, express or fast passenger or breakdown van train?	4	4 consecutively
Is line clear for ordinary passenger or empty carriage train?	4	3 pause 1
Is line clear for branch passenger train?	4	1 pause 3
* Bank engine in rear of train	4	2 pause 2
* Fast train approaching	5	3 pause 2
Is line clear for fish or meat train?	5	5 consecutively
,, ,, express goods or cattle train?	5	1 pause 4
Is line clear for fast goods or through mineral train?	5	4 pause 1
Is line clear for light engine?	5	2 pause 3
* Obstruction—danger signal	6	6 consecutively
Take off slot—train waiting	7	3 pause 4
* Stop and examine train	7	7 consecutively
* Signal given in error (cancel last signal sent)	8	8 consecutively
* Train passed without tail lamp	9	9 consecutively to the signal station in advance 4 pause 5 to the signal station in the rear
* Train divided	10	5 pause 5
* Shunt train for following train to pass	11	1 pause 5 pause 5
* Vehicles running away on wrong line	12	2 pause 5 pause 5
* Section clear, but station or junction blocked	13	3 pause 5 pause 5
* Vehicles running away on right line	14	4 pause 5 pause 5
* Opening of Signal station	15	5 pause 5 pause 5
* Test signal	16	16 consecutively
* Closing of signal station	17	7 pause 5 pause 5
* Time signal	18	8 pause 5 pause 5

The signals marked thus * must be returned by the signalman receiving them to show that he understands them, but in all cases he must allow sufficient time to insure the signal being completed before he commences to return it or reply to it.

The "Call attention" signal is to be used when it is necessary to call the attention of the signalman at the next signal station,

The disc block telegraph instrument shows three signals :—

The disc showing half white and half red indicates "Line blocked."

The white disc showing full on indicates "Line clear."

The red disc showing full on indicates "Train on line."

All fixed signals show a white and red light only, except in a few special cases.

"Is line clear?" signal must never be sent until "Train arrived" has been received for the previous train, and the disc has been put to half red and half white.

The Interlocking of Points and Signals.

This system was invented by Mr. Saxby, in 1856, to prevent accidents which constantly occurred under the mode of working then in use. Points were worked by levers on the ground, and were perfectly independent of the signals, and it frequently happened that signals were lowered when points were in the wrong position. Mr. Saxby brought the point and signal-levers together, and interlocked them so that it was impossible for an "all-right" signal to be given which

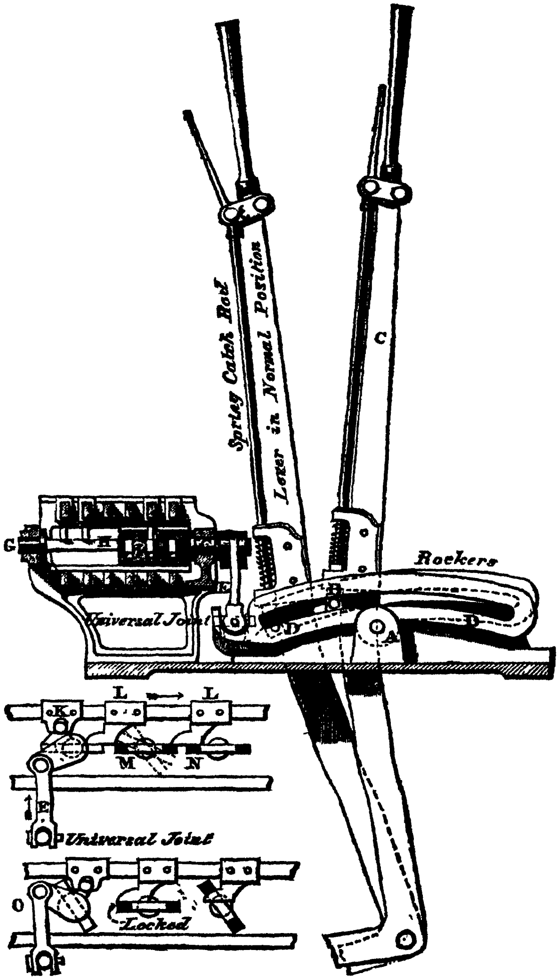

Spring Catch Rod
Lever in Normal Position
C
Rockers
G
H
E
B
Universal Joint
D
D
A
L
L
K
M
N
E
Universal Joint
O
Locked

Fig. 4.

was not in accordance with the position of the point-levers.

Fig. 4 shows the system as now used by Messrs. Saxby and Farmer. The locking-gear is worked by the movement of the spring catch-rod, the lower end of which carries a stud upon the block B, which travels in the curved rocker B.

The raising of the catch-rod causes the rocker to move into the position shown in the diagram, and this rocker is connected by a universal joint, E, with a lever which gives motion to the locking-bars. The locks are clearly shown L; they are fixed to the locking-bars in such a manner that some of the spindles are free to move as at M, and some are locked as at N. It therefore follows that until the point-lever C has been placed in its proper position it is mechanically impossible for the signal-lever to be moved; and when the signal-lever has been moved to lower a signal, the point-lever becomes in its turn locked.

The principle is thus briefly explained, and the marvellous development of the system will be clearly understood from the numbers of levers which are all properly interlocked at the following stations:—

The signals at the Waterloo Bridge terminus are controlled from a signal-box having 109 interlocked levers; the new south cabin at Brighton has 240 levers; and the London Bridge Station north cabin, west side, has no less than 280 levers. This is, indeed, a wonderful specimen of the interlocking system. In a day of twenty-four hours about 600 trains and engines pass, and between 8 and 10 A.M. there are about, 90 trains; and these figures do not include

shunting operations. This vast cabin is worked by four men at a time, each set being on duty for eight hours.

The Union of the Block and Interlocking Systems.

It has already been shown that the block and interlocking systems are excellent in themselves, so far as they go; but experience conclusively proves that they do not go far enough. They require to be carried a step further, and, in place of two independent appliances, be united in one complete system or combination. At present there is nothing to prevent a signalman, by mistake, from taking off his outdoor signals at a time when his block instruments indicate that the line is not clear, and such mistakes are constantly leading to collisions.

So long as the outdoor signals exhibited to the engine-drivers truly repeat the state of the block section ahead, safety is provided for, but we know from experience that the present system is liable to, and actually does, at times, break down in consequence of mistakes made by signalmen, arising either from human fallibility, or from excessive hours during which signalmen are too frequently kept on duty.

When we consider the number of serious and fatal accidents that have occurred in consequence of these mistakes, it is needless to waste words in arguing how great must be the value of any inventions which will prevent such accidents by establishing an absolute mechanical block system, which cannot fail from the error of a signalman.

The idea of combining the block and interlocking

systems, and of making the train itself assist in providing for its own safety by telegraphing its arrival and departure from signal-boxes, is not a new one. Messrs. Hodgson, Saxby and Farmer, Sykes, and others, have worked diligently, and with greats uccess, to attain the desired security.

Hodgson's patent apparatus was tried on the Tunbridge Wells and Eastbourne branch of the London, Brighton, and South Coast Railway. The author accepted the invitation to inspect the same, August, 1881, and formed a very high opinion of its merits. One of the principal improvements was the introduction of a treadle near each signal-box, electrically connected with the telegraph instruments in the signal-boxes, rendering it necessary in the working of the block system that the actual running of each train should exercise control over the signalmen. At first the treadles were sometimes liable to get out of order by the repeated blows received from the wheels of a train passing at full speed. This difficulty has, however, been entirely and successfully overcome by Messrs. Saxby and Farmer, by causing the deflection of the rail itself acting upon the short arm of a lever always in contact with the underside of the rail, the means of making an electrical contact through the long arm of the same lever with the telegraph instruments in the signal-boxes, thus taking off a lock that prevents the signalman from moving the handles of the block instruments, by which the signal "Line clear" is given to the box in the rear. The latest improvements have been recently examined by the author, and consist of apparatus containing interlocking appliances for a box with seven levers for working

points and signals, and the block telegraph instruments for the exchange of train signals with stations on either side.

The block instruments are as usual placed upon a shelf over the signal levers, the handles of the instruments being connected by vertical rods with the interlocking gear; or, in other words, the "block" system and the interlocking apparatus are combined in one and the same mechanism, and cannot be manipulated in a contradictory manner.

The block instrument handles are attached to hollow spindles in the centre of which are the plungers. When the handles are moved to the right (which is the "Line clear" position), they work interlocking gear, so as to interlock the point and signal levers in any manner necessary to the requirements of the traffic. When the handles are moved back to "Line blocked" they are stopped in the mid-stroke or vertical position, and become locked, and cannot again be moved to "Line clear," neither can the point and signal levers be again moved until the train for which "Line clear" was given has arrived and actually passed over the treadle apparatus, and thus by its weight deflected the rail and completed the electric circuit. A current of electricity is then sent through the magnet of the block instrument and unlocks the handle, which can then either be restored to its normal position to unlock the point and signal levers, or it can be again moved to the right to give "clear" for a following train to approach. Only one wire isused for the block signal instruments and bells of both up and down lines. (See also electric slot, p. 58.)

The Sykes's system of signalling has for a long time been in use. In May, 1876, Cambria Junction, on the

London, Chatham, and Dover Railway, was fitted with it in such a manner that if the signalman had accepted a train from Canterbury Junction he could not accept one from Loughborough, or if he accepted one from Loughborough, the apparatus was so locked that he could not then accept a train from Canterbury Road until he passed the train, *and put his signal back to "danger."*

These signals have also been working perfectly satisfactorily for several years on the Metropolitan District Railway, and have been introduced upon a section of the Great Western; at Dumfries Junction, upon the Glasgow and South-Western; three signal-boxes upon the Great Eastern; and Walpole Junction, U.S.A.

In the Sykes's system each station is provided with the usual train signal apparatus, ordinary semaphores, and signal levers. Beyond each station is an automatic treadle actuated by the passage of a train to manipulate a circuit extending back to the indicator at the station; each station is also provided with an arm galvanometer, which serves as an additional indicator. In front of the signalman is placed a case containing two indicators, which show respectively through the openings in the case. One indicator reads either "clear" or "blocked," and refers to the condition of the section of the line beyond, while the other reads either "Train on line" or "Train passed," and refers to the condition of the section of the line in the rear.

The former indicator is connected with the lock in such a manner that when it reads "clear" the lock is lifted and the lever is free, but when it reads "blocked" the lever is locked.

Sometimes, instead of the automatic treadle, a plat-

form plunger is employed, under the control of the station staff, and is used when a train has been seen to pass out of the station, an arrangement which is found particularly advantageous in foggy weather, when the train cannot be seen by the signalmen.

The combination of the block and interlocking apparatus has for some time been a useful and practical appliance, and there can be no reason why so many railway companies continue to employ the old system, which depends so much upon human fallibility.

Defective Signalling.

Attention has recently been again directed to the very important subject of defective signalling on railways. Engine-drivers constantly complain, and with very good reason, of the way in which signals are frequently placed; but it is only in rare cases, or *after* an accident has actually occurred, that their complaints receive attention, or that improvements are introduced. Unfortunately the selection of position and the erection of signals are usually placed in the hands of a separate department. On many railways the engine-drivers and locomotive department have little or no control over the signal arrangements, and frequently when drivers have pointed out faults, they have been informed that "their duty is simply to obey signals." Instead of a *good standard system* being adopted and strictly carried out, the drivers on many lines state that "the signals are placed anyhow—here, there, and everywhere, and that, instead of improvements being made in this respect, some of the latest signals are placed in the very worst places, and on the wrong side of the line." On several occasions the author has examined signals at stations,

junctions, and sidings where drivers have made mistakes, and in every case has found that the true cause was the defective state or position of the signal.

One of the first and most important requirements of efficient signalling is that all signals shall be placed upon the left-hand or proper side of the line to which they refer. If by any chance it is absolutely impossible to place a signal in such place the *special* attention of engine-drivers should be directed to the fact by a special printed notice. Each roadside station or signal-cabin should be provided with a "distant," "home," and "starting" signal, and an "advanced starting signal" where necessary, in each direction. Distant signal-arms should always be of the "swallow-tail" pattern. Home signals should in every case be placed so as to completely protect any train which may be crossing from one line to another, or into a siding, so that an engine-driver may run as far as the home signal without any fear of being foul of points and crossings which such signal is intended to protect. "Starting," or "advance starting," signals ought always to be placed at least the length of the longest train (say engine and fifty waggons) beyond the home signal or siding points, so that all shunting can be performed without the engine ever having to pass the starting or advanced starting signal at danger, even a few yards. In very many cases these signals are placed at too short a distance, and the drivers are then obliged, and required by rule, to pass them at danger, in order to draw the tail of the train over the points. Signals which control the exit from the sidings should always be "discs" placed low down near the ground, so as to avoid any chance of their being mistaken by a main-line driver. In several cases the author sees *siding*

signals which consist of an arm placed upon the home signal-post, and the arm is generally connected to the points, so that when the points are open the signal *must* be off, no matter if the train is going into or out of a siding; on many occasions two drivers have considered the signal was lowered for them, and collisions have resulted from this dangerous system of signalling. All junctions should be provided "in the facing direction" with as many distant signals as there are branches and home signals, so that when a driver sees the proper "distant" lowered, he may know that the "home" signal is also "off" for him to proceed in the desired direction, and that the facing-points are properly placed and locked. All distant signals ought always to be so interlocked that they cannot be taken "off" till after the corresponding home signal has been lowered. In all cases where two signal boxes are situated near together, the "*distant*" from the one box must be a swallow-tail arm placed upon the "home post" of the next. In every instance the home signal must be the top arm, the distant arm second. They ought also to be *slotted* in such a way that the distant can never be taken "off" when the home is "on." The home signal-men ought to be able to place *both* to danger as soon as a train passes, so as to avoid conflicting signals being given. Three or four arms referring to different lines should never be placed one below the other on *one* post. Each line should have a separate post placed in the proper position on the left of the line to which it refers. All lines should be worked on the absolute block system; and the signal "Line clear" should *never* be sent to the box in the rear until the train has passed and is well forward on its journey, or has been

shunted into a siding clear of the main line; and after the "Line clear" signal has been accepted for a train to approach, no shunting on or crossing of the main line should be permitted. To avoid mistakes which may be made by signalmen, one of the systems of electrically combining the block and interlocking apparatus should be adopted.

No system of signalling can be considered efficient or safe unless it provides mechanically for an interval of space between all trains, and in practice it is absolutely necessary for a train to be protected, if it break down or stop unexpectedly between two stations, as when standing at a station or between fixed signals.

In consequence of the recommendation of the Amalgamated Society of Railway Servants, that one code of signal regulations and one pattern of signal should be adopted throughout the kingdom, a committee of the railway companies has been appointed to consider the whole question of signals and signal lights; and Major Marindin, reporting on a case of collision on the North British Railway, hopes that their deliberations may be successful in elaborating a uniform system for all lines, which, looking to the numerous cases in which two or more companies have running powers over one and the same piece of line, is most essential to the public safety. Signals on various lines differ to a very great extent. For instance, a white light on the Great Northern is to be treated as "danger," but on most other lines as "all right." A green light is sometimes to indicate "caution," at another station it is the "all right" signal, and again it is employed simply to indicate the back of a signal, and in such position it does not in

any way refer to an engine-driver. On some railways a purple light is an "all right," and on others a "danger" light. All signal arms should be counter-weighted to fly to danger in case the rod breaks.

When railways were worked by "time" a caution signal was used, and a green light employed; but now, under the block system, "caution" has no meaning, as the line should be either clear or blocked.

It would be an advantage if the green light were now made the only *all right* signal; and green should not be employed as a back-light, as it is in practice often mistaken; and if the white light were discarded as a signal it might with advantage be adopted as a back-light to show that the signal was "on," and it has been suggested that when the signal is "off" no back-light would be required, especially as signals remain in that position for such a very short time with the present short block sections.

Controlled or Slotted Signals.

The ordinary mechanical slot system enables a signalman at one signal-box or station to control the outdoor starting-signal worked by another signalman at the station in the rear in such a manner that it cannot be taken off without the concurrent action of both signalmen; but either man, independently of the other, can instantly place the signal to danger.

Fig. 5 shows the usual arrangement of "slot." It will be seen that there are two levers and weights—one worked by each signalman; and unless both be raised, the signal cannot be lowered. As soon as both men require the signal to be lowered, the weights take the position shown in the dotted lines, and the arm

falls by its own weight, assisted by the small balance-weight as illustrated.

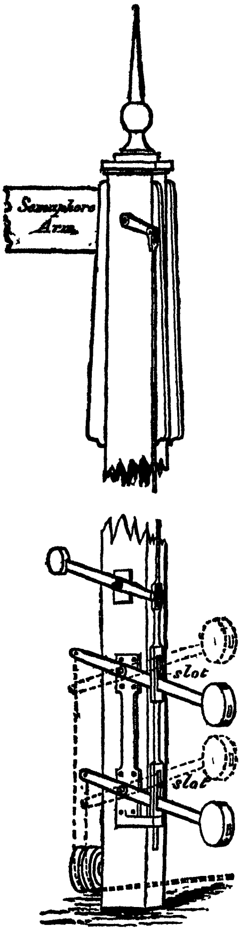


Fig. 5.—Mechanical Slot Signal Apparatus.

The mechanical slot is therefore perfect in its action for moderate distances, and will even work well up to a distance of 1,000 yards. The "electric slot-signal," Fig. 6, derives its name from the fact that it has the same objects as the mechanical slot, but it has the very great advantage of being capable of controlling the working of a signal by means of electricity at any required distance. The action of the apparatus is as follows: When a current of electricity is sent through the electro-magnet M of the electric slot it keeps the armature, which is attached to the vertical lever H, attracted, and on pulling the wire, raises the weighted lever fixed at the foot of the signal-post, and the arm is lowered to the all-right position. If now the current of electricity is cut off, the attraction ceases, and the vertical lever falls away from the magnet, and striking the clutch C, releases the wire, and the signal-arm is raised to "danger" by means of the weighted lever. The treadle

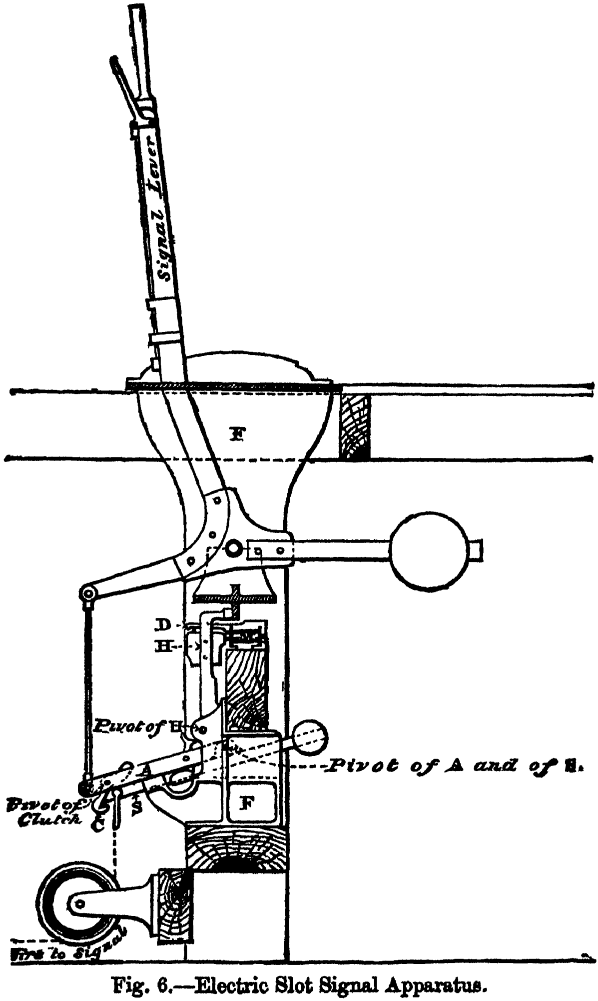


Fig. 6.—Electric Slot Signal Apparatus.

apparatus already referred to enables the passage of the train itself over the line to act upon the electric slot signal, and places it to "danger" at the rear, even in case a signalman should omit to do so. By this arrangement and combination points and facing-point locks must be set in the proper position *before* "Line clear" can be signalled for a train to approach. Points cannot be moved for shunting or other purposes when the line has been signalled "clear." The "Line clear," or "Train out of section" signal cannot be sent a second time until the approaching train has arrived at and passed over the treadle. The outdoor starting-signal cannot be lowered to permit the entrance of a train into a block section without the consent and concurrent action of the signalmen at each end of the section, and it must be reset to "danger" behind every train; and this is insured by the action of either signalman, or, in case both should forget, by the action of the train itself passing over the treadle. When once the starting-signal has been lowered and placed to "danger" after a train has entered the section, either by the signalman or by the action of the treadle, it cannot be again lowered until that train has passed out of the section and over the treadle at the other end, and until the signalman in advance has given "Line clear" for another train to enter the section.

The apparatus is so constructed that the signalmen cannot work it otherwise than in the proper order. The omission to give any of the ordinary block signals, or to put the outdoor signals to "danger" after the passing of a train, prevents the apparatus being again worked, as, after receiving "Line clear," the starting-signal is lowered and put to "danger" in the

rear of a train; and "Line blocked" must first be sent before "Line clear" can be given a second time for another train.

The Improved Facing-point Lock and Duplex Detector.

The invention has been designed and perfected by Messrs. Saxby and Farmer to obviate the danger which arises when a connecting-rod between a set of points and the locking apparatus breaks. Under the old system such mishap would permit of the point-lever being placed in its intended proper position, but the points, Fig. 7, would have remained unmoved, and would actually be lying in a contrary direction to that which the signal, if given, would indicate.

The detector lock, Fig. 8, consists of a double-action plunger, which, when the points stand in one direction, is pulled, and when in the other, pushed into the appropriate hole in the tie-bar between the tongues of the points. Thus, if, owing to a broken rod, the points have not been moved, the signalman is warned of the fact by being prevented from lowering any signal which would be contrary to the actual position of the points themselves.

As is the case with the ordinary locking-bars, whilst a train is travelling through the points, it is itself master of the situation; not even the signalman can inadvertently change their position until the whole train has passed clear of the locking-bar. It therefore follows that by the union with the "block" instruments, as already described, an accident is rendered impossible from the failure of facing-point rods and connections.

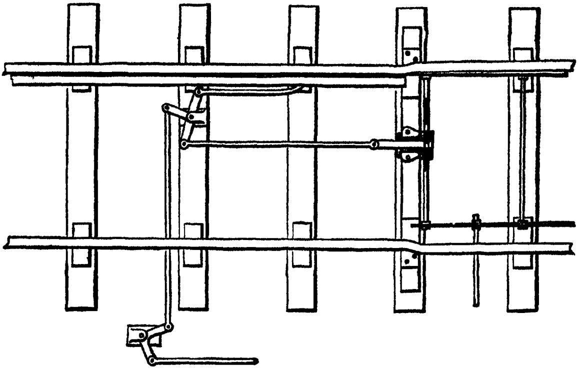


Fig. 7.—Facing Point-lock.

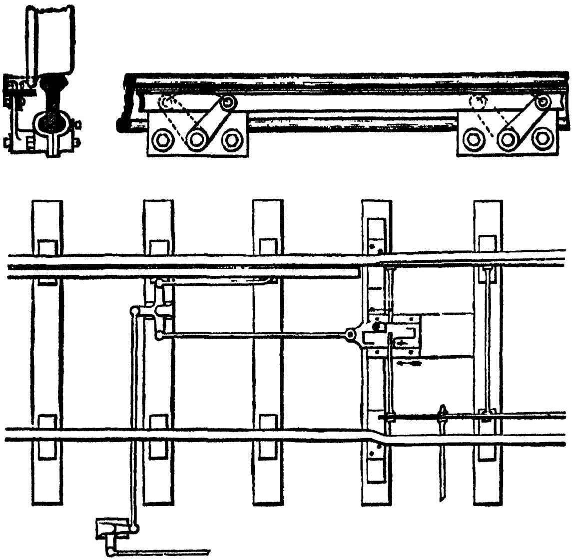


Fig. 8.—Improved Duplex Detector.

Junction Block Working.

Junction block working should always be adopted, and very strictly carried out. No two trains should ever be allowed to approach a junction at one and the same time, either upon converging or crossing lines, otherwise the required certain interval of space is actually reduced to nothing more than the thickness of the junction signal-post, Fig. 9 (Plate II.). The "Line clear" signal for one should be accepted, the other refused, so that the second train may be stopped at the box in the rear. At all double-line junctions it is possible for a train in one direction to be cut in two by one in the opposite direction; therefore, no two trains which can in any way come into collision at the junction crossings should be accepted by a junction signalman when working under proper rules.

A recent improvement provides mechanically for junction block working, and renders it impossible for trains to approach at the same time.

Locking Gear for Signal-arms.

Attention should here be directed to the importance at all junctions of placing an actual lock upon the signal-arm itself, as well as upon the levers in the signal-box. The ordinary interlocking frame prevents wrong signals being lowered by the man in charge, so long as the connections, rods, and wires are in proper order; but if (as was the case at Earl's Court recently) a rod should fail, the system is rendered useless. To avoid this danger, Mr. Davis, of the Great Eastern Railway, invented, and Messrs. Saxby and Farmer manufacture an efficient apparatus, which appears to

satisfactorily insure the impossibility of two conflicting signals being off at one time. To prevent this, the action of lowering one signal is made to actuate an extension of the rod to the other conflicting signal. This "lock-rod," as it is called, works a mechanical hooked bell-crank which directly locks the arm itself, which must always be "on" when the conflicting signal is lowered, as the same action which lowers the one locks the other. Having described the method of locking, let it be supposed a fracture has occurred in the rod working a branch home signal at a junction, and that the signal has been lowered to, or stands "off," and remains in that position after the signalman has returned the lever in his box to the normal position, as the balancing of the arm is altogether insufficient to overcome the friction of the rollers in the long length of rod or wire. The action of returning the lever of the branch signal to "danger" would, of course, unlock the levers in the locking frame in the box, but should the signalman, without knowing of the failure of the rod, attempt to lower the main line signal, he would be unable to do so, as the actual locking on the main arm would prevent its being taken "off." It will be found, by taking any example, that whichever rod breaks, no two opposing signals can be standing off at one time, and it has the further advantage of immediately acquainting the signalman that something is wrong with the apparatus.

The method can be carried out with signals of any type, whether worked by rod or wire, and is stated to be comparatively inexpensive in its application. It can be applied, however complicated the station or junction may be, and is certainly the only direct

mechanical lock between conflicting signal-arms. The locking device of one arm may be made to act upon and control the locking device of one or several other arms directly between the signals themselves, without the intervention of the movement of the levers; or the locking device on any signal-arm may be connected back to the levers in the locking frame, so as to lock or unlock any levers as may be required.

It would appear that if so simple and effective a method of preventing accidents can be applied for a comparatively small cost, railway companies should give this matter their earnest consideration. Signal connections will always be liable to failure, for whatever care is taken in their manufacture, absolute security cannot be guaranteed by any tests of the material, so that a method by which these failures are rendered harmless is of the greatest importance, both to the public and the servants.

Clearance or Train Safety Bars.

Railway collisions frequently occur in consequence of a train being kept waiting for a considerable time at a "starting" signal, and being either out of sight of the signalman, or in consequence of fog the man forgets the presence of such train and lowers his home signal in the rear for the following train. To avoid these accidents, clearance bars should be adopted. They consist of a series of locking bars placed between the starting signal and the signal-box, and so long as a train or engine is standing upon this portion of line the block instrument and the home signal are locked at "danger," and a signalman is unable to commit an error.

SINGLE LINES.—THE TRAIN STAFF SYSTEM.

Some of the most serious accidents which have occurred from defective systems of signalling and working have been occasioned by trains meeting upon single lines of railway; for instance, the collisions at Norwich and near Radstock.

On small branches, or sections, with light traffic, only one engine in steam or two coupled together should be allowed at one time.

All other single lines should be worked under the train staff and ticket system, combined with the absolute block system of signalling.

So long as the "staff" is at one end of the section, trains can be permitted to leave with a ticket, but after the staff itself has been sent away in charge of the last driver, no train must, under any circumstances, be started until its return.

A few companies work single lines by means of telegraph messages sent from a crossing agent at the principal station, who arranges where trains in opposite directions are to pass each other. This system is extremely dangerous, and has caused many accidents, as the least mistake in a telegram may result in a serious collision.

CHAPTER IV.

RAILWAY BRAKES.

In nearly all the more calamitous of the great railway accidents of recent years, those which have been attended by the largest destruction of life, rolling-stock, and property, it has been constantly proved that even if the first cause of the catastrophe, such as the breaking of axles, or failures of signals, &c., were admitted to have been unavoidable, all the worst consequences would have been either entirely prevented, or very greatly mitigated, if the train had been fitted with an efficient automatic continuous brake; it is, therefore, an extraordinary fact that the introduction of such brakes has been delayed for years in this country, and the story of the battle of the brakes, when ultimately written, will form one of the most curious, but certainly not the most creditable chapters in English railway history.

As soon as railways were introduced, it became apparent that it was essential to public safety that trains should be capable of being stopped in the least possible distance in case of accident, or of an obstruction on the line, and this necessity constantly increases as the weight and speed of trains become so marvellously augmented. An ordinary main line express train may be considered as equal to about 220 tons,

including the engine and tender; such a train running at a speed of 60 miles an hour, passes over a space of 88 feet per second, and has a *vis viva*, or stored-up force, of equal to no less than 26,452 foot-tons; and if the train comes into collision, it will strike another train or any obstruction with a blow or destructive force equal to a ton weight falling from a height of five miles. To stop the train in the shortest space, and destroy this enormous momentum is the great object of efficient brakes. For many years the hand brakes upon tenders and guard's vans were considered sufficient, but experience has long since proved that they do not provide for safety.

Mechanical and non-automatic continuous brakes were next invented; they are useful under ordinary circumstances, and so long as they remain in order, but they are absolutely powerless in cases of emergency, or at the very moment when required to act as life-saving appliances. All non-automatic brakes are slow in action, liable to fail at any moment, and in case of accident are rendered useless. These very serious defects led to the introduction of automatic or self-acting brakes. Every engine, tender, and vehicle should carry its own store of brake force ready for instant use; it therefore follows that if every coupling in the train were to be broken, each portion or vehicle would stop itself. This principle has been worked out, and perfection appears to have been reached in the form of continuous brakes fitted to every wheel capable of application by the driver (or either of them when two engines are employed), by either of the guards, and self-acting in case of accident.

In June, 1875, the celebrated Newark brake trials were conducted under the direction of the Royal Com-

mission on Railway Accidents; the ground selected was part of the Nottingham and Lincoln branch of the Midland Railway, extending from near Newark to Thurgaton, since known as the racecourse.

The following table shows the systems tried and the results obtained when the utmost was done to stop the trains by the application of all available brake-power, the use of sand, and the reversing of those engines not provided with brake blocks.

NEWARK TRIALS (SERIES 1, SECTION E).

Railway Company.	Name of Brake.	Speed, miles per hour.	Distance of stop in feet.	Retarding force in percentage.
Midland	*Westinghouse automatic	51½	825	10·64
L. & Y.	*Fay and N.-E. engine .	57½	1,385	7·94
L. & N.-W.	†Clark and Webb . . .	47½	964	7·79
Midland	*Barker hydraulic . .	50½	1,101	7·64
L. & Y.	†Fay and L. & Y. engine	45½	913	7·60
G. N.	†Smith vacuum . . .	45	905	7·47
Caledonian	†Steel McInnes	49½	1,120	7·33
L. B. & S. C.	*Westinghouse vacuum .	52	1,533	5·88

The brakes are placed in the order of merit and efficiency, as shown by the percentage recorded in the last column.

To accurately estimate the relative value of a brake *is very necessary, and as trains are of different weights,* and running at various speeds, direct comparison is impossible, but the desired information is easily obtained by establishing a "basis or comparison," and expressing the average efficiency of the retarding force of the brakes in percentages of the weights of the trains.

This method of comparison is thus worked out: the

* Brakes applied to engine wheels.
† Engines reversed being unprovided with brakes.

weight and speed of a train being known, the foot-tons of energy accumulated in it are at once found by multiplying the speed by itself (squaring the speed), also by ·0334, and by the total weight of the train. Now, the work done by a brake in stopping a train, must, of course, be equal in amount to the total energy of that train, and this work is made up of the retarding force multiplied by the distance through which it acts; it therefore follows that the retardation of a brake equals the energy, or *vis viva* of the train divided by the distance run in making the stop. To facilitate calculation, it is found most convenient to express the relation or proportion of retarding brake force in the form of a percentage of the total weight of the train; thus, if a train of 200 tons weight has been stopped by the application of a brake force of 20 tons applied to the brake blocks, it is clear that it can be expressed as a retarding force of 10 per cent.

The following useful formula enables the average brake force exerted in making any given "stop" to be calculated: thus, suppose a train to be stopped from 50 miles an hour on the level in 835 feet, 50 squared multiplied by 3·34 and divided by 835, gives the result 10·; or thus, $3{\cdot}34\,\frac{50^2}{835} = 10{\cdot}$, which means that the average brake force was 10 per cent, or 10 tons for every 100 tons of the total weight of the train.

The celebrated Newark trials were followed by others, on the North British Railway, December, 1876; North Eastern, May and June, 1877; Belgian State Railways, 1876 and 1877; Germany (near Cassel), August, 1877; North Eastern Railway, October, 1878; Paris Lyons Railway, April, 1879; North Eastern Railway,

July, 1879; Lancashire and Yorkshire Railway, July, 1880.

On the 14th and 15th July, 1879, Captain Galton conducted experiments on the North Eastern Railway, near York, with a train of sixteen vehicles fitted with the Westinghouse automatic brake; total weight, 207 tons 19 cwts., 91·5 per cent on braked wheels.

Brake applied by driver.					
Speed per hour.	Gradient.	Stop in yards.	Time in seconds.	Retardation in percentage.	Distance in yards which would have been run had the speed been 50 miles an hour.
51	Down in 1,200	207	14·75	14·0	198
48	Level	190	14·5	13·5	206
50·5	Level	225	16·5	12·6	220
Train "slipped." Brake automatically applied.					
52·5	Level	223	16·75	13·7	203
55·	Level	208	15·5	16·1	172
59·5	Level	290	19·0	13·5	206
50·	Level	173	13·25	16·0	173
52	Up 1 in 200	187	14·75	15·6	178
58	Level	260	16·75	14·4	193
Brake applied from van against engine with full steam on.					
27	Level	68	9	11·0	252

Captain Galton also conducted a series of experiments on the Lancashire and Yorkshire Railway at Gisburn, July, 1880.

The following table gives the averages of all stops reduced to 50 miles an hour on a level with the allowance made for the different percentages of the braked portion of the train to the unbraked portion, allowance being also made for the rotating momentum of the unbraked wheels in the train :—

Brake.	Stops by driver.		Stops from van.		Slip stops and automatic action.	
	Distance in feet.	Retardation in per cent.	Distance in feet.	Retardation per cent.	Distance in feet.	Retardation per cent.
Westinghouse, G. N. train	727	11·49	—	—	441	18.94
Westinghouse, L. & Y. train	716	11·66	895	9·33	668	12·50
Eame's vacuum .	752	11·10	914	9·14	754	11·08
Sanders' vacuum	891	9·37	1,111	7·19	722	11·57
* Fay-Newall .	817	10·22	—	—	—	—

Since the trials mentioned in 1875—1879 and 1880, several brakes have been removed, and others have been perfected or improved. Under these circumstances the Amalgamated Society has recently resolved that some further trials are now required, and if the necessary facilities can be obtained, it is prepared to carry out or be represented at such experiments.

As long ago as the 30th August, 1877, the Board of Trade forwarded a circular to the companies, in which the advantage of having uniform brakes upon all lines was pointed out, and stating that there had been no attempt on the part of the various companies to agree upon what are the requirements which, in their opinion, are essential to a good continuous brake. In the opinion of the Board of Trade, the conditions should be as follow :—

(*a.*) The brakes to be efficient in stopping trains, instantaneous in their action, and capable of being applied without difficulty by engine-drivers or guards.

* The Fay-Newall brake was applied by two guards to two sections of four vehicles.

(*b.*) In case of accident, to be instantaneously self-acting.

(*c.*) The brakes to be put on and taken off (with facility) on the engine and every vehicle of a train.

(*d.*) The brakes to be regularly used in daily working.

(*e.*) The materials employed to be of a durable character, so as to be easily maintained and kept in order.

The celebrated conditions, it will be noticed, are so obviously necessary and practical, that they are scarcely open to discussion.

It might have been supposed that the various companies would have at once attempted to secure both an efficient brake and uniformity of system; but unfortunately this has not been the case. Companies which work in direct connection, and exchange a large amount of rolling-stock, do not even employ the same system; the result is that the vehicles of one company cut off or render useless a portion of the brake power upon another company's train.

So great has this difficulty become, that it has been necessary to actually fit a large number of vehicles with two complete brakes, of course at double cost. Sir Joseph Pease, M.P., director of the North-Eastern Railway, has recently created considerable amusement in railway circles, by his statement in the House of Commons, that "it was an advantage to have two brakes, as when one brake failed they use the other." Of course, the statement is not correct, and the only reason why vehicles have two systems is to work with other brakes upon other railways.

CONTINUOUS BRAKES IN USE IN THE UNITED KINGDOM ON THE 31ST DECEMBER, 1885.

The continuous brakes return for the second half of the year 1885 has been issued, and although it furnishes evidence (if any were required) that the companies are not taking the necessary steps to arrive at a general system, it is satisfactory to find that most of the brakes recently fitted either are, or are said to be, automatic.

The form of return has been amended and improved by the Board of Trade, but the information recorded is in many instances inaccurate.

The following table shows the total amount of stock fitted and unfitted on the 31st December, 1885 :—

—	Engines fitted with brakes.	Engines fitted with apparatus for working the brakes.	Carriages, &c., fitted with brakes.	Carriages, &c., fitted with pipes or chains only.
Total amount of stock returned as fitted with brakes which appear to comply with conditions of Board of Trade .	2,291	1,389	21,033	4,259
Total fitted with brakes which do not comply . .	1,218	1,386	13,168	3,287
Total fitted	6,284		41,747	
Not fitted with any continuous brake .	1,040		9,500	
Total passenger rolling stock therefore	7,324		51,247	

From these figures it will be seen that out of a total of 7,324 engines and 51,247 carriages, &c., only 2,291 engines and 21,033 vehicles have brakes which even

appear to fulfil the conditions laid down by the Board of Trade, and these figures would be considerably reduced if the return were properly corrected.

Having given the total amount of rolling-stock fitted with brakes, reference should now be made in detail to the separate totals for each system.

Name of brake.	Engines fitted with brakes.	Engines fitted with apparatus for working brakes.	Vehicles fitted with brakes.	Vehicles fitted with pipes or chains only.
† Automatic vacuum	†66	1,213	6,559	804
* Vacuum automatic .	708	3	2,775	696
Steel McInnes . . .	3	—	29	8
§ Vacuum and Westinghouse	—	—	2	12
Westinghouse automatic	1,514	85	11,095	2,738
Clark's chain . . .	—	12	46	5
Clark and Webb's chain	—	738	3,106	484
Wilkin and Clark's chain	—	13	79	—
Fay's	—	—	1,219	—
Fay and Newall's . .	—	—	350	—
Newall's	—	—	321	—
W. Parker-Smith . .	—	—	3	—
Smith's vacuum . .	1,170	92	5,686	1,743
Vacuum (Webb's) .	—	619	2,581	1,056
Westinghouse pressure	48	—	350	—
Total .	3,509	2,775	34,201	7,546

* At first sight the "automatic vacuum" and "vacuum automatic" brakes may appear to be one and the same system; the former refers to the brake known as the Sanders-Bolitho, which "leaks off," and the latter to the Vacuum Company's system, which does not leak off. A certain number of vehicles on the Midland Railway have been altered from the "leak-off" to the "ball-valve" system, but the return does not furnish the number of brakes so changed.

† Sixty-one of these engines are upon the Midland Railway. They are provided with a "steam" brake capable of being applied in conjunction with the automatic vacuum. In case of accident, however, the engine and tender part, the steam pipe is broken, and the

The above totals do not include 134 goods engines on the North Eastern Railway fitted with the Westinghouse brake and used for excursion traffic.

The following table shows the amount of rolling-stock fitted with two complete systems of brakes, so that both act on the same blocks :—

Railway, N.E.	Ten Engines.	Westinghouse automatic. Smith's vacuum.
	Vehicles.	
West Coast Joint S.	280	Westinghouse automatic and Webb vacuum.
Caledonian . . .	31	
L. & N.-W. . . .	95	
Midland S. J. S.. .	85	Westinghouse automatic —automatic vacuum.
Midland	117	
G. & S. W. . . .	*	
East Coast Joint S.	108	Westinghouse automatic —Smith's vacuum.
N. E.	44	
N. E.	13	Westinghouse automatic —Midland vacuum.
N. E.	8	Westinghouse automatic L. & N. W. vacuum.
L. & Y.	2	Westinghouse automatic —vacuum automatic.
Total	783	

The progress made during the half-year cannot be considered satisfactory; the total stock fitted shows but a small increase; many of the brakes fitted are inefficient, for instance, the "leak-off" and the simple vacuum, and in the case of the London and North-Western vacuum, the large nominal increase is not

"steam" brake rendered useless at the very moment when required. Such a brake cannot, therefore, fulfil the condition of being efficient in case of accident.

§ Fourteen vehicles are returned with vacuum and Westinghouse brake. This is not a brake system, but simply means that they are fitted with two brakes.

* G. & S. W. Co. number not given.

progress, but simply the change of brakes from the chain to the vacuum. To remove one brake and fit another, which does not fulfil the Board of Trade conditions, is but a useless waste of money, as a still further alteration must ultimately be made.

The Westinghouse automatic brake is in general use on the North Eastern, Great Eastern, Brighton, Caledonian, North British, Glasgow and South Western, Great North of Scotland; and, to a less extent, on the London, Chatham, and Dover, Midland, and also on several minor railways.

The Vacuum Brake Company's, or Gresham's automatic vacuum is employed generally on the London and South Western, and Lancashire and Yorkshire Railways, and to a less extent on the Taff Vale, Belfast and Northern Counties, and a few other lines.

The Sanders-Bolitho, or "leak-off" automatic vacuum brake is used on the Midland and Great Western railways only.

Smith's non-automatic vacuum is employed to a considerable extent on the Great Northern, South Eastern; Manchester, Sheffield, and Lincolnshire; Great Southern and Western Ireland, Metropolitan. Midland, and to a less extent by a number of smaller lines.

The Clark-Webb chain brake is principally used on the North London, and London and North Western but upon the latter line it is being removed and replaced by a non-automatic vacuum brake that is adopted only by the North Staffordshire Company.

The author, having during the past seventeen years inspected and worked all the continuous brakes in use, is of opinion that at the present time there are but two

systems that can be considered efficient, or that are at all likely to come into permanent use, namely, the Westinghouse automatic air brake, and the Vacuum Company's, or Gresham's automatic vacuum brake.

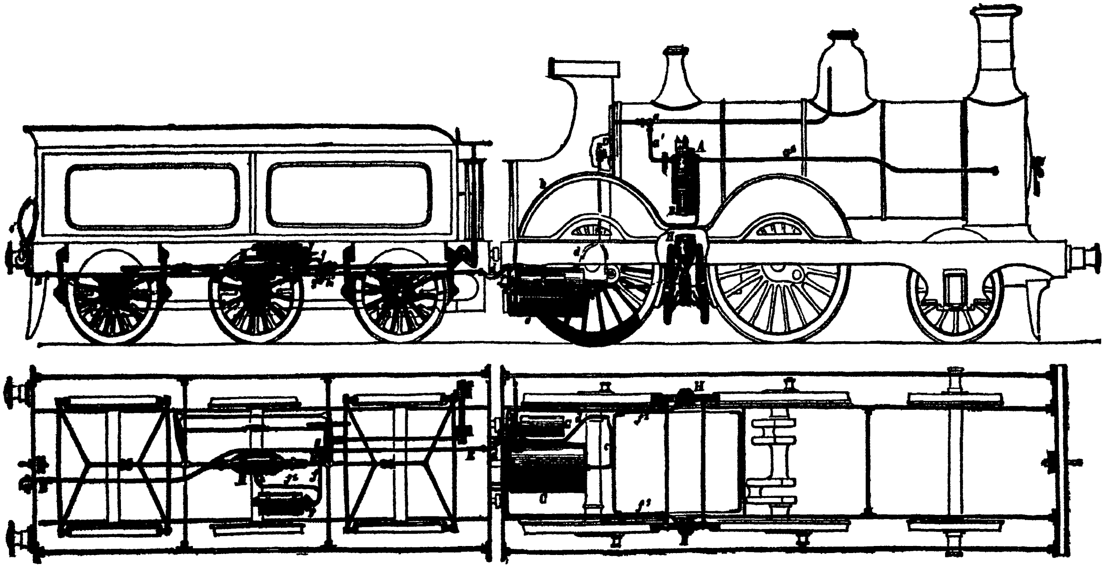
These two inventions may be said to represent the best of their respective classes or principles, and are, therefore, fully described and clearly illustrated. It would no doubt have been better and cheaper to have had one universal brake for the whole country; but as at present this seems almost impossible, it is not too much to hope that the companies will use either one or other of these two brakes, and rolling-stock intended for through or exchange traffic should be provided with the complete apparatus for each system: this would be a great stride towards the settlement of the brake question.

The action of the Westinghouse, or pressure system, is based upon the use of compressed air, or pressure greater than the 15 lbs. of the atmosphere; whereas the vacuum system is applied by the force of the atmosphere acting upon one side of a piston, from the opposite side of which about 12 lbs. of the atmospheric pressure has been purposely drawn out or removed.

Description of the Westinghouse Automatic Brake.

The Westinghouse automatic brake is continuous throughout the train, and is operated by compressed air stored in a main reservoir on the engine, and in small reservoirs, one upon each engine, tender, and carriage, all connected by a pipe running the length of the train. There is also on each vehicle a triple

Fig. 10.—Engine and Tender fitted with the Westinghouse Automatic Brake.



View from below.

valve and brake cylinder, with pistons connected to the brake levers.

Maintaining the pressure in the brake-pipe keeps the brakes off; but letting the air escape from the brake-pipe, purposely or accidentally, instantly applies the brakes, by allowing air to pass from the small reservoirs into the brake cylinders.

Fig. 10 shows the brake complete on an engine and tender.

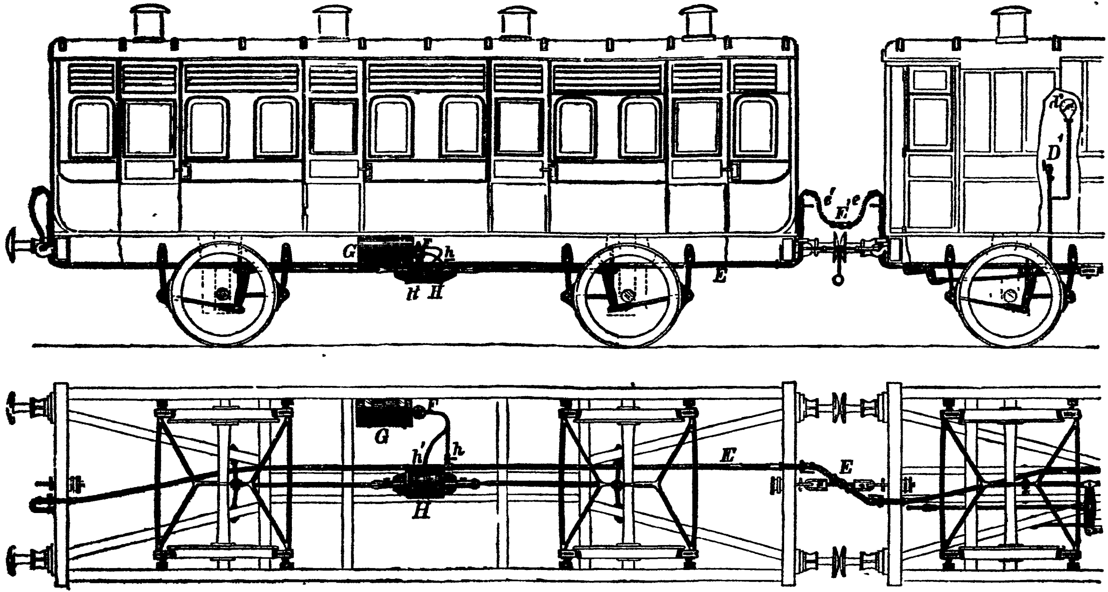
The engine, tender, and every vehicle of a train is fitted with the following parts, to be found on Figs. 10, 11, and 12: A triple valve, F, by means of which the instantaneous automatic action is produced, in conjunction with a small reservoir, G, in which is stored the compressed air for applying the brakes; a brake cylinder, H, with pistons and rods connected to the brake levers and blocks. Upon the engine is also placed the steam-engine and pump, A B, which produce the compressed air; a main reservoir, C, for storing the air necessary for releasing the brakes and recharging the small reservoirs; a driver's brake valve, D, which regulates the flow of air from the main reservoir into the brake-pipe for charging the train and releasing the brakes, and from the brake-pipe to the atmosphere for applying the brakes. A single line of pipe, E, called the brake-pipe, extends the whole length of the train. Each van has a guard's valve connected to the brake-pipe, and a gauge to indicate the pressure of air.

General Principle of Action.

Compressed air is the power employed to work the brake.

The air, compressed by a pump on the locomotive to,

Fig. 11.—Carriage and Van, fitted with Westinghouse Brake.



View from below.

say, 70 lbs. or 80 lbs. to the square inch, fills the main reservoir on the engine, and flowing through the driver's brake valve and main pipe, also charges the supplementary reservoirs throughout the train. When a train is running, uniform air pressure exists throughout its length—that is to say, the main reservoir on the engine, the pipe from end to end of the train, the triple valves, and the supplementary reservoirs are all

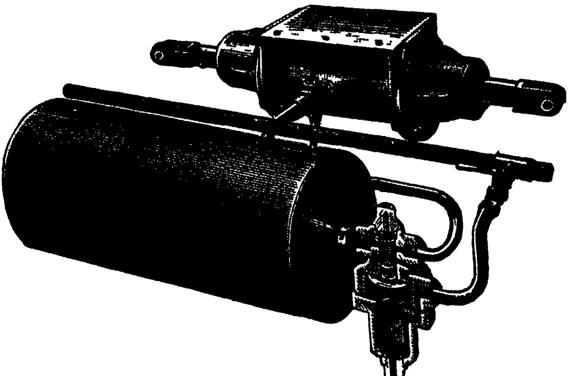


Fig. 12.—Enlarged View of Triple Valve, Brake Cylinder, and Supplementary Reservoir.

charged ready for work, the brake cylinders being empty and the brakes off. The essential principle of the system is that maintaining the pressure keeps the brakes off, but letting the air escape from the brake-pipe purposely or accidentally instantly applies them. As soon as the pressure in the brake-pipe is lowered, the triple valve piston on each vehicle is moved down by the greater pressure above it stored in the small reservoir, the air is then allowed to pass instantly into the cylinder, force out the piston and rods, and thus

cause the blocks to press against the wheels. It follows, therefore, that the brake may be applied by the driver or any of the guards, or, if necessary, by a passenger*, as well as by the separation of a coupling or the failure or injury to a vital part of the apparatus, whether due to an accident to the train or to the brake; and as the brake on each vehicle is complete in itself and independent, should the apparatus on any one carriage be torn off, the brake will nevertheless remain applied for almost any length of time upon the remainder of the train.

The brakes are released by an increase of pressure in the main pipe, produced by the driver allowing air to pass from the main reservoir along the train. This moves up the triple valves, recharges the small reservoirs, and at the same time allows the air which had forced out the pistons to escape into the atmosphere, and the blocks to be withdrawn from the wheels by the spiral spring within the cylinder. By closing the half-inch cock, *h*, on the branch leading from the train-pipe to the triple valve, the brake on any vehicle can be cut out of the system. A release valve, *h'*, is also placed upon each cylinder, so that in the event of the brakes being applied by the separation of the train, or the breaking of a pipe, or when the locomotive is not attached, they can be released by allowing the air to escape from each brake cylinder direct. This release valve can be opened from either side of the carriage by pulling a cord, and as it closes automatically there is no fear of its remaining open after being used.

To enable vehicles to be detached without setting

* If desirable the brake can be placed under the control of passengers; but the author does not consider this necessary.

the brakes there is an inch cock at each end of every vehicle, which also serves to close the brake-pipe at the ends of the train. These cocks must always be opened after connecting the hose couplings E, and always closed before separating them.

It will thus be seen—

1st. That it is the air stored in the small reservoirs which applies the brakes, while the air in the main reservoir releases them; and

2nd. That the brakes are applied by a decrease of pressure in the brake-pipe, and taken off by restoring that pressure.

So that, whether by the driver or guard operating his brake-valve, the accidental separation of the train, the breaking of a pipe, or any other means by which the pressure in the brake-pipe is suddenly reduced below that in the small reservoirs, the brake will be put on, and will remain on. It is, therefore, automatic in its action, and is a "tell-tale" as to its own condition, and the author finds it to completely fulfil all the Board of Trade requirements.

Description of the Vacuum Brake Company's Improved Automatic Vacuum Brake.

Those who remember the vacuum brake as introduced into this country about the year 1874 by Mr. Smith will hardly be able to recognise it in its present improved form, the differences between the old and the present systems being so numerous that practically nothing remains but the principle of producing the vacuum; in other words, the present automatic vacuum is a new and distinct appliance, and in place of the old non-automatic and inefficient

apparatus a brake has been perfected which "appears" to comply with the celebrated conditions of the Board of Trade.

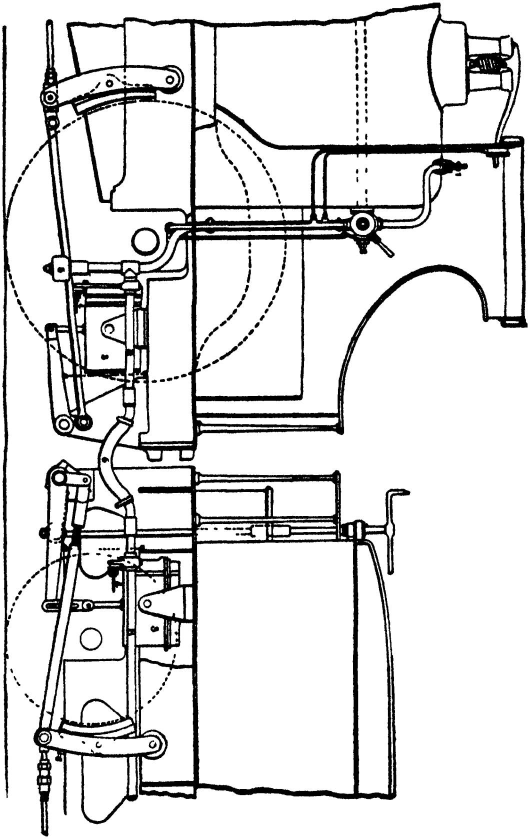


Fig. 13.—Engine and Tender fitted with Vacuum Automatic Brake.

The brake is worked by atmospheric pressure of about 24 inches of mercury or 12 lbs. per square inch. This

partial vacuum is obtained by means of a steam-worked ejector fixed upon the engine, Figs. 13 and 19, and sup-

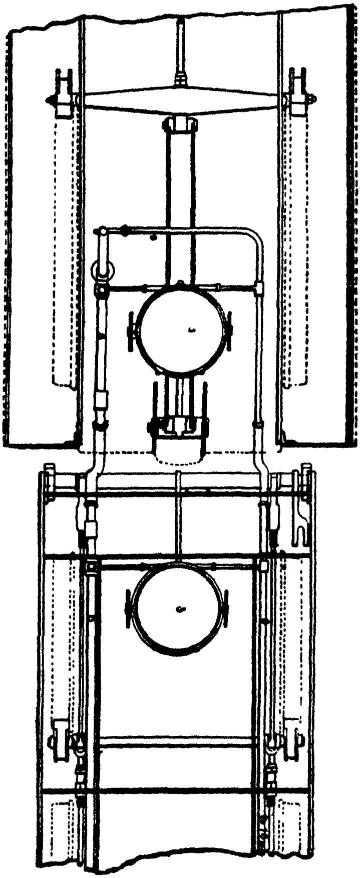


Fig. 14.—Plan.

plied with steam from the locomotive boiler. The action

of the ejector is inductive, the effect of the steam jet being to draw out the air from the train-pipe and all vessels in connection therewith. Beneath each vehicle in the train is fixed a cylinder, which is in communication with the train-pipe, Figs. 16, 17, 18. When the

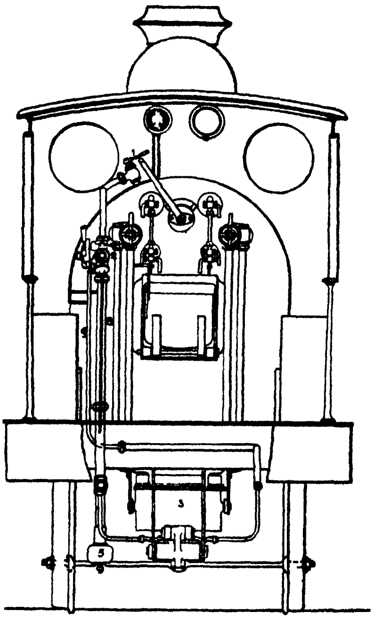


Fig. 15.—End View.

steam is turned through the ejector all these cylinders are emptied of their contents, but when from any cause, whether the accidental division of the train or the intentional act of the driver or guard, air is admitted to the train-pipe, a small ball-valve is caused by the rush of air to change its position, by doing which

the passage from the train-pipe to one side of the piston

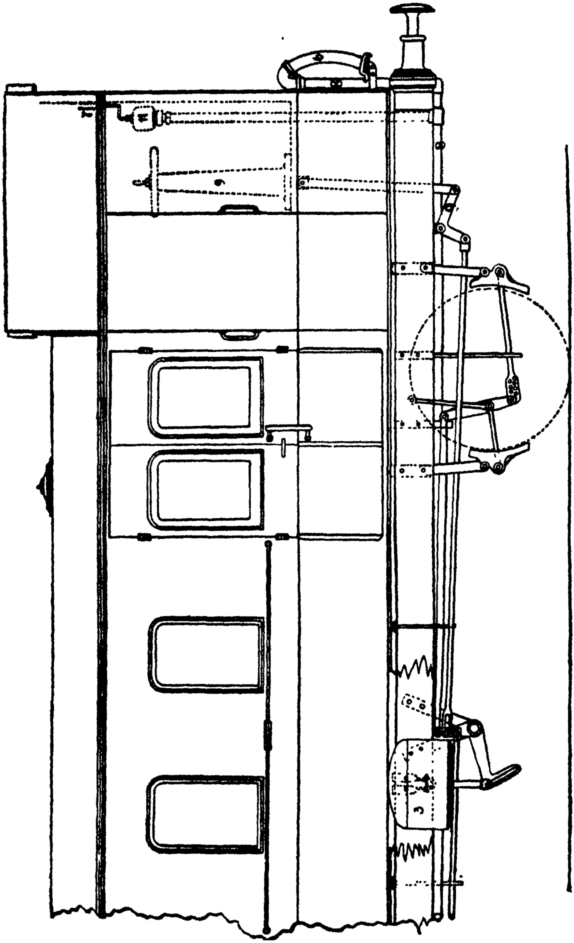


Fig. 16.—The Vacuum Automatic Brake fitted to Carriages and Vans.

is closed, whilst the other side is left open to the train-

pipe. The piston is thus out of equilibrium, and the

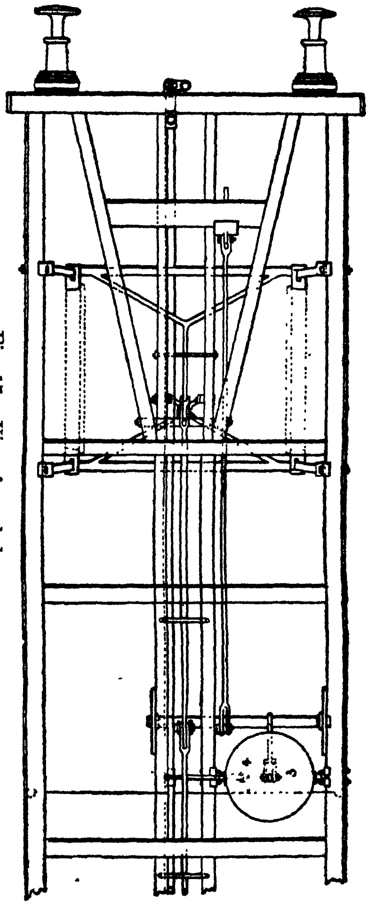


Fig. 17.—View from below.

unbalanced pressure upon its underside forces it up,

and thus brings the brake blocks to bear upon the wheels.

When it is desired to release the brakes the air inlet valves are closed, and the ejector being set to work again draws out the air from the train-pipe and cylinders. As soon as the pressure on the under side

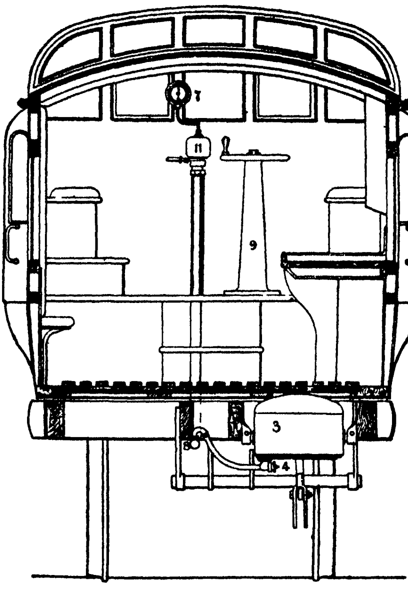


Fig. 18.—End View of Van.

of the piston is reduced to an equality with that on the top side, the ball-valve opens the top side passage to the train-pipe, and the two sides of the piston being in equilibrium the brakes fall off the wheels by their own weight and the weight of the descending piston. Hence, in running, a vacuum is maintained throughout

all the pipes and cylinders by means of the ejector, and the brakes are applied by destroying the vacuum on one side only of the brake pistons.

The general arrangement of the apparatus will be at once understood from the elevations and plans showing it attached to engines and vehicles, Figs. 13, 14, 15.

Having described the principle of the brake, the

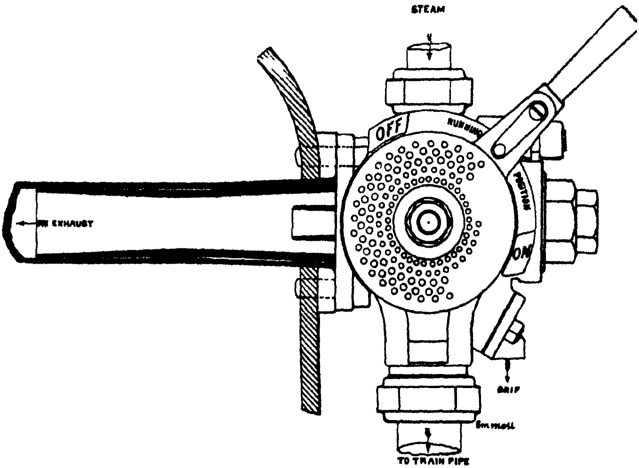


Fig. 19.—Ejector.

following particulars of details will show how the required results are obtained.

Fig. 19 is the combined ejector by which the vacuum is formed and maintained in the train-pipe and brake cylinders. It is arranged so that, when the handle is in the position shown, a small supply of steam is allowed to pass the cones of the small continuous ejector, for the purpose of keeping the vacuum from

destruction by leakage. When the handle is at ON the train-pipe is filled with air through the numerous perforations of the handle disc. When at OFF steam passes through the large ejector at its full power,

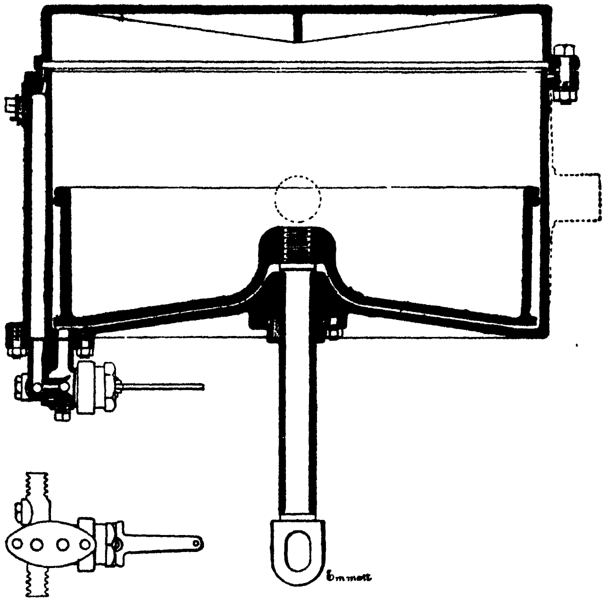


Fig. 20.

withdrawing air from the pipes and both sides of the brake pistons, and thus releasing the brake.

The formation of the vacuum is brought about by the inductive action of the passage of a small amount of steam around the conical nozzles, the steam carrying with it a very much larger quantity of air. By the ejector handle the driver can easily either fully apply

or release the brakes, or he can adjust the pressure of the brake blocks to suit any necessary requirement.

Fig. 20 is a sectional view of the engine and tender

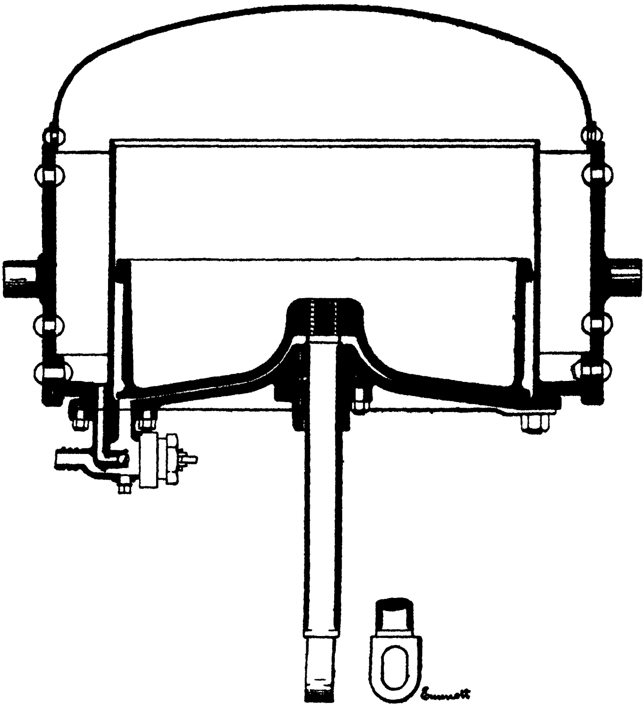


Fig. 21.

brake cylinder; it is provided with a piston made air-tight by means of a rolling ring which allows freedom of motion to the piston. To the piston is attached a rod which is directly connected with the brake levers, as

shown, and to allow for the curvature of the path described by the moving levers, the cylinder is swung on

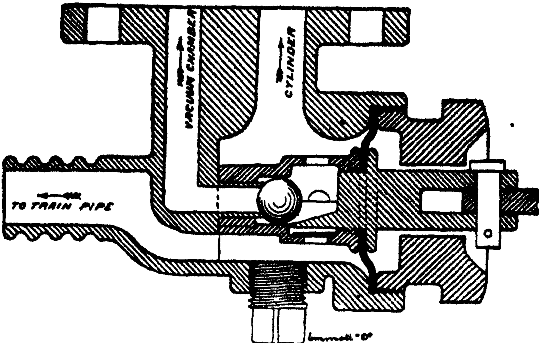


Fig. 22.—Section of the Ball Valve.

trunnions. Upon the underside of the cylinder is fixed the ball-valve.

Fig. 21 shows the cylinder used for carriages and

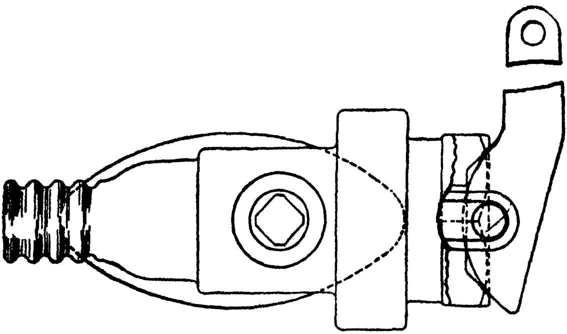


Fig. 23.—Elevation of Ball Valve.

vans; it is similar to those for engines, except that it is placed within an outer casing of wrought iron, to

which are attached the trunnions upon which the cylinder swings. The outer casing acts as a vacuum reservoir, and its effect is to minimise the effect of compression of the rarefied air above the piston when the brakes are applied.

Fig. 22 is a section of the ball-valve which provides for the automatic action of the brake. It consists of a chamber having free communication with the train-pipe, and with the lower side of the brake cylinders, to each one of which one of these valves is attached, and forms part of the connection between them and the pipe. From the chamber of this automatic valve is also another passage, which leads to the top side of the brake cylinders, but this passage has a ball-valve to close it. This ball, however, has no tendency of itself to close the passage, being neutral, owing to the horizontal direction in which it rolls. It will therefore be seen that when the ejector is put in action the ball will allow air to flow out from above the brake pistons as freely as it flows from below them. When, however,

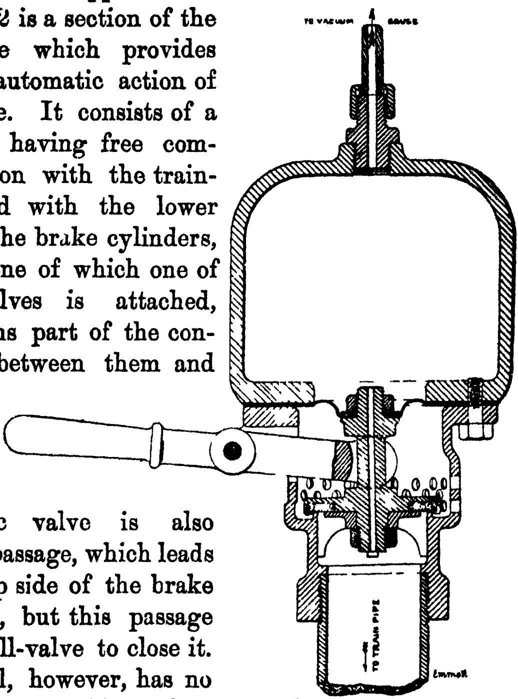


Fig. 24.—Guard's Valve.

air is admitted to the train-pipe, by the driver, guard, or by the passenger, or by the breaking of the train, the rush of air to the now empty cylinders easily rolls the balls before it and against their seatings. This closes the top side passage, and the pressure of the atmosphere is left unbalanced upon the undersides of the pistons, thus forcibly applying the brakes. The ball will remain against its seat until it is set free by the ejector again drawing out the air from behind it.

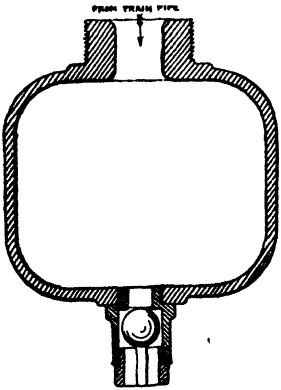


Fig. 25.

When it is desired to release the brakes of a vehicle, in a siding for example, and uncoupled from the engine, this is done at once by pulling at the lever shown connected to the valve, or rather to the little cage which carries the ball. By pulling the lever the ball is drawn off its seat by the encircling cage, and air rushing in releases the brakes.

Fig. 24 is the guard's valve, by means of which he can apply the continuous brake. Above the valve is a small vacuum chamber, in which is placed the guard's pressure or vacuum gauge. This chamber communicates with the train-pipe by means of the small hole through the valve-spindle. The opening at its base is made tight by a disc of india-rubber, which allows full movement of the parts without allowing air to pass.

When the driver applies his brake he destroys the equilibrium between the pressure in the upper or

gauge chamber and that in the train-pipe, and in obedience to the difference the guard's valve rises and admits air to the pipe through the holes shown round the valve chamber. By this means is insured the quicker application of the brake all along the train.

A drip-cup and valve is shown (Fig. 25), to collect any moisture which accumulates in the pipes.

An enlarged view of the coupling between the

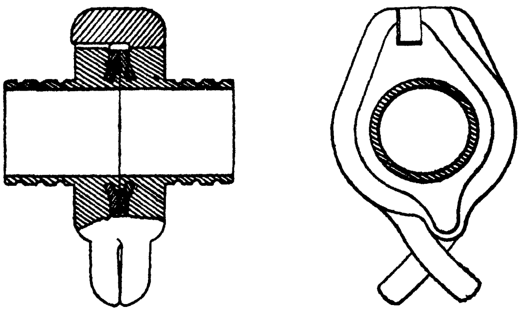


Fig. 26.

vehicles is shown (Fig. 26). To couple the hose-pipes, one must be taken in each hand and lifted sufficiently high to hook the bottom horns together, then by lowering the coupling, the top horns fit into the slots. This coupling is becoming generally adopted for all forms of vacuum brakes. To close the brake-pipe at each end of the train, the coupling is placed upon a stop-plug.

CHAPTER V.

THE BREAKING OF LOCOMOTIVE DRIVING AXLES.

MAJOR MARINDIN, in his report upon the disaster which occurred at Bullhouse, near Penistone, on the Manchester, Sheffield, and Lincolnshire Railway, upon the 16th July, 1884, remarked that the accident should lead locomotive engineers to consider carefully the relative advantages of engines with inside cylinders and crank axles, as compared with engines with outside cylinders and straight axles; of steel axles as compared with iron axles; and of cranks hooped with wrought-iron bands, as compared with cranks having the additional strength provided by an increase of metal in the webs of the crank itself. In pursuance of that recommendation, a return was prepared, showing the number of driving axles in use, and the proportion thereof broken when running, and taken out in the shops after the detection of flaws, in the United Kingdom, during the year 1883, the details of which appear in the summarised returns given on the following page, from which it will be seen that "no less than one in every sixteen driving axles in use during the year 1883 were either broken or condemned." Such a fact as this is certainly a serious one for reflection.

The advocates of the outside cylinder engines

ENGINE AXLES BROKEN OR DEFECTIVE, 1883.

Description.	Number in use.		Broken in running.		Taken out in shops.	
	Iron.	Steel.	Iron.	Steel.	Iron.	Steel.
			Per Cent.	Per Cent.	Per Cent.	Per Cent.
Crank axles without hooped webs . . .	2,867	4,733	3·1	0·9	6·0	3·8
Crank axles with hooped webs . . .	4,121	1,222	0·85	0·9	7·7	0·7
Straight axles, outside cylinders	438	1,467	5·0	0·5	2·7	0·8
Total driving-wheel axles	7,426	7,422	2·0	0·8	6·8	2·7
Total	14,848		2·8		9·5	

	Number in use.	Broken in running with passenger trains.	Broken in running with goods trains.	Taken out in shops flawed.
Crank axles . . .	12,943	70	108	680
Straight axles . .	1,905	10	19	24
	14,848	80	127	704

frequently claim that they avoid the danger of a crank axle; but from the above figures it appears that out of 1,905 straight-driving axles, 10 were broken when running with passenger trains, 19 when running with goods trains, and 24 were taken out in the workshops after detection of flaws; it will therefore be seen that 5·5 per cent. of straight-driving axles broke when running.

It is satisfactory to notice that a large proportion of defective driving axles (704) were discovered and taken out in the shops, and, doubtless, a more careful

and frequent examination will reduce the number "broken in running;" but still, growing flaws will exist, which no care or investigation can detect. It is often stated, and, indeed, is almost taken for granted, that a crank axle is, and must be, weaker than a straight axle; but there seems to be no proof that this is the case in practice, for when the various strains upon a crank axle are carefully calculated and worked out, they are found to fall far short of a force which would be sufficient to fracture a good sound axle.

The question is constantly asked, "What is it that breaks a crank axle?" and it is one which deserves very careful attention. As the weight resting on the axle, and the pressure of steam on the pistons, are certainly not enough to account for the fracture or failure, other reasons must be looked for, and other causes examined. When an engine is running at high speed, there is a greater or less amount of oscillation; this is kept in check by the flanges of the wheels, and great strain is put on the axles. Points and crossings are generally laid to gauge or even tight, and it frequently happens that the flanges of the wheels are thus pinched, and it will be at once seen that this action must exert an enormous force upon the axle by the tendency to bend it upward in the middle. This force is greatly increased with the size of the wheel, as the leverage or length of the spokes is greater. The author is of opinion that the strains which increase growing flaws, and ultimately end in fracture, are in a very great measure due to the force communicated to the axle by the wheels and flanges. He has, therefore, given this question of "side thrust" very careful attention, and advocates the plan of turn-

ing the driving-wheel flanges thinner than the others, in order to avoid the pinching action and side shocks as far as possible. At the present time, great difference of opinion appears to exist with regard to the relative advantages of iron and steel crank axles.

The following tabulated statement shows the number of axles in use in this country to December 31, 1883 :

Railway.	Iron crank axles	Steel crank axles.	Outside cylinder engines.
Furness	6	112	1
Great Eastern	37	380	198
Great Northern	709	19	37
Great Western	1,362	410	38
Lancashire and Yorkshire	573	356	8
London and North Western	—	2,174	137
London and South Western	6	170	324
London, Brighton, and South Coast	90	329	1
London, Chatham, and Dover	34	134	—
Manchester, Sheffield, & Lincolnshire	215	282	12
Metropolitan	—	—	56
Metropolitan District	—	—	42
Midland	1,453	232	16
North Eastern	1,383	66	13
North London	—	37	50
North Staffordshire	15	99	9
South Eastern	—	324	1
Taff Vale	132	7	3
Caledonian	30	3	657
Glasgow and South Western	13	264	13
Great North of Scotland	2	—	53
Highland	—	3	69
North British	581	2	29
Great Northern of Ireland	77	47	5
G. S. & W. of Ireland	—	172	—
Midland Great Western of Ireland	22	80	—
Total of 58 minor lines	250	253	133
Total, United Kingdom	6,988	5,955	1,905
Total crank axles	12,943		
Total driving axles	14,848		

From this table it will be seen that the Great Northern, Great Western, Midland, North Eastern, and North British Companies appeared to be in favour of iron cranks, the London and North Western being the most important supporter of steel. The advocates of steel axles frequently assert that the matter is simply one of "strength," and that as steel is stronger than iron, it must be better for use in axles; but the author contends that very many other matters have to be considered besides the mere tensile strength of iron and steel. An axle may be too stiff and too strong, and this extra stiffness or rigidity causes extra strain and shock to be thrown upon it, which ultimately ends in its failure; therefore it will be seen that an axle must have a certain amount of elasticity, and that it is not so much a question of what is sometimes called "strength" as of capability to resist strains. It is a well-known fact that some straight axles have been made too rigid, and they have broken in consequence, but such breakage has been almost entirely prevented by reducing their diameter at the middle, and giving them more elasticity; in other words, paradoxical as it may sound, the axles have been strengthened by weakening them. It has been truly stated that more iron than steel axles fail every year; but, on the other hand, the fact must be remembered that there is a far larger number of iron cranks in use, also that they run a much greater mileage than steel before they break.

The following table, compiled from the Board of Trade Returns, shows the total number of driving axles which have broken when running during the past five years, together with the average mileage:—

Year 1881. 262 crank or driving axles failed.
177 were made of iron.
85 ,, ,, steel.
Average mileage of 167 iron axles = 197,574 miles.
,, ,, 80 steel axles = 181,842 ,,
Year 1882. 242 cases.
156 were made of iron.
86 ,, ,, steel.
Average mileage of 150 iron axles = 206,857 miles.
,, ,, 83 steel axles = 192,453 ,,
Year 1883. 247 cases.
173 were made of iron.
74 ,, ,, steel.
Average mileage of 171 iron axles = 213,719 miles.
,, ,, 72 steel axles = 199,471 ,,
Year 1884. 200 cases.
138 were made of iron.
62 ,, ,, steel.
Average mileage of 135 iron axles = 216,333 miles.
,, ,, 59 steel axles = 173,287 ,,
Year 1885. 190 cases.
127 were made of iron.
63 ,, ,, steel.
Average mileage of 125 iron axles = 226,037 miles.
,, ,, 63 steel axles = 219,644 ,,

It will at once be noticed that in every year the "steel" had the least number of cases, but the "iron" axles ran the greater mileage before breaking.

A very interesting tabulated statement has been published by Messrs. Vickers, Sons, and Co., giving details and mileage of all the steel crank axles of their manufacture, the highest mileage attained being shown in the following table :—

Name or number of engine.	Railway company.	Mileage.
"Munster"	Great Northern of Ireland (N. Division)	547,965
17	South Eastern	521,246
251	London, Chatham, and Dover . .	479,515
1,003	Great Southern and Western of Ireland	477,388
36	Glasgow and South-Western . .	420,517
152	Manchester, Sheffield, and Lincolnshire	415,097
—	North London	412,536
Old 10. R.2.	Maryport and Carlisle	396,753
204	London, Brighton, and South Coast .	391,115
5	Great Eastern	376,186
7	Waterford and Limerick . . .	360,959
23	Belfast and Northern Counties . .	348,213
266	Midland	326,102
14	Great Northern of Ireland (S. Division)	319,115
55	*Taff Vale	252,938

The above figures are useful, showing as they do what steel crank axles can attain, but at present it is to be regretted that there does not appear to be any similar comparative table in existence giving the performance of iron axles.

Through the courtesy of several companies and officials, the author has lately been supplied with a very considerable amount of valuable information, which, now carefully tabulated, adds to the data upon this important subject. So far as these inquiries have at present extended, they appear to point to a conclusion, that if a steel crank axle is defective or flawed when new, the failure takes place at an early period in its life, and that if it runs for 150,000 or 200,000 miles, there is a great probability that it may afterwards run a very great distance.

* With the exception of the Taff Vale axle, all the others were at work when the details were compiled.

It will be understood that this opinion is not mentioned in a spirit of assertiveness, but is simply recorded in order that the circumstances may be considered and further investigated by any person who may be devoting attention to this branch of locomotive engineering. If the above conclusion proves to be founded on sound data, it will be important, as in such case we shall probably have to wait until some of the cranks which have run an unusual mileage ultimately break, which may be a period of several years.

From the table (page 97) it will be seen that considerable difference of opinion appears to exist with regard to the value of hooping the webs of the cranks, there being 5,343 with such hoops, and 7,600 without. The author, having obtained all available details from the various companies, had some experiments made, and also witnessed others, the result being that it appeared that when a crank web breaks nearly or quite straight across, the hoops are of the greatest use in holding the crank together; but, on the other hand, when the fracture occurs in a slanting direction, the hoop is not only rendered of no value, but it even tends by its tightness to force the broken parts out of the required position. The hooping of a crank practically lengthens it about 2 inches, and there are very many engines running in which hoops cannot be employed in consequence of there being no available space between the crank and the under side of the boiler.

To overcome the above-mentioned difficulties, the author designed and applied for a patent for an improved method of strengthening the webs or throws of cranks, Fig. 27. The crank having been manufactured

in the usual manner, the improvement consists in

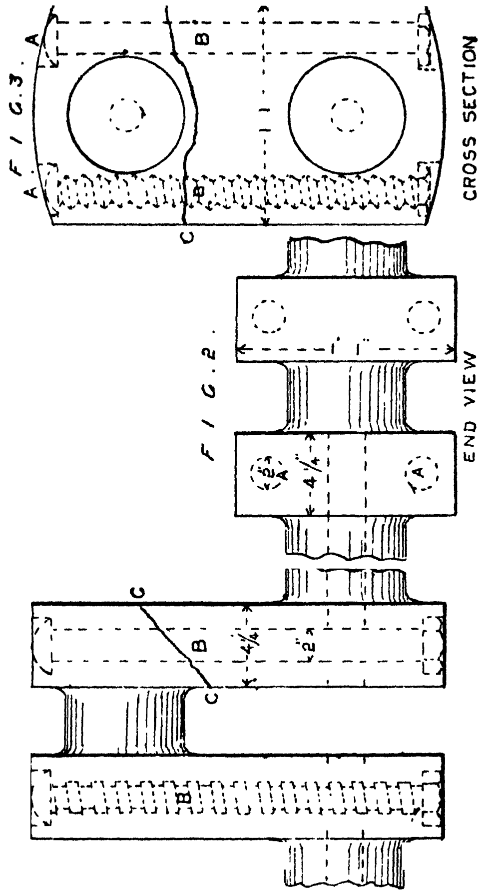


Fig. 27.—Stretton's Patent Crank.

drilling two holes of about 2 inches diameter through

the length of the webs, A A. A bolt, pin, or screw, B, is then passed through the said holes.

Each bolt should be made of steel, having a tensile strength of not less than 40 tons per square inch, and can be either screwed into the web or made a driving fit and forced in by any desired hydraulic pressure, and afterwards secured by a nut and split-pin.

C C shows the position of a slanting fracture, and the manner in which the bolts would strengthen the crank when working, and in case of breakage, they would hold the web in place in such a manner that the wheels of a locomotive engine would be prevented from leaving the rails, and thus give time for the engine-driver to bring his train to rest and prevent a disaster.

The patent is dated 7th September, 1885, No. 10,556; it has become the sole property of Messrs. Vickers, Sons, and Co., Sheffield, by whom it is being introduced and manufactured.

The annexed diagram, Fig. 28, illustrates the crank-axle of the Manchester, Sheffield, and Lincolnshire Company's engine, No. 434, which broke when running at a speed of about 50 miles an hour, and caused the Penistone disaster, by which twenty-four persons were killed and sixty-four injured. The position of the fracture is clearly shown across the outside web of the right-hand crank.

This axle was made by Messrs. Taylor, of Leeds, and was forged in the usual manner out of an ingot of cast steel, the slot pieces being knocked out after it was annealed.

The webs were 14½ inches in width, but without hoops, the outer webs being a quarter of an inch

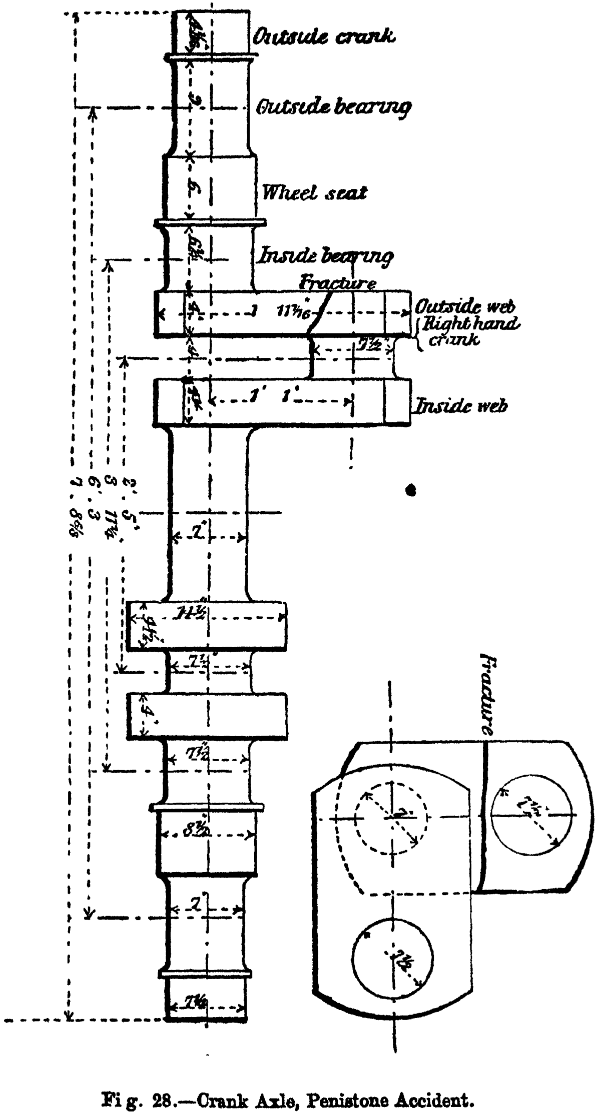


Fig. 28.—Crank Axle, Penistone Accident.

thinner than the inner ones. It is difficult to account for the fracture of the crank at that particular time, for, although there was a growing flaw in the web, the author measured it, and it did not exceed 4½ inches in length and 2 inches in depth at the deepest part, and it is probable that the flaw did not extend to the surface till the fracture occurred.

According to the tests of pieces cut from this crank after the accident, the metal was a mild, soft steel of good quality, with a tensile strength of 27 tons per square inch.

Elongation 29 per cent.
Contraction 40 per cent.

The analysis showed the following results:—

Carbon	·230
Manganese	·482
Silicon	·063
Sulphur	·027
Phosphorus	·065
Iron (by difference)	99·133
	100·000

The engine had cylinders 17 inches diameter, 26 inches stroke, with driving-wheels 6 feet 3 inches diameter, having 15 tons 14 cwts. resting upon them. The crank was well designed, and contained ample material to give the required strength; however, we know that it broke with disastrous results after running only 50,776 miles.

It may be here mentioned that several railway companies specify that one out of fifty axles shall be tested, and stand five blows from a weight of 2,000 lbs. falling from a height of 20 feet, upon the axle, upon supports 3 feet 6 inches apart, the axle being reversed after each

blow. Straight axles for engines should be able to stand being bent double when cold, without signs of fracture. On some lines it is expected that crank axles should run 200,000 miles, and if they fail at a less mileage, the manufacturer is required to replace them.

The author does not advocate the adoption of either iron or steel for cranks, his object being to fully and impartially continue his inquiries with a view to drawing out practical data and conclusions upon this subject, which it is known and admitted is not yet so well understood as it should be, and requires careful study. At present perhaps the most important information necessary is full details of every axle which fails, specially stating the exact point at which the fracture occurs; it is to be hoped that these data will in future form part of the Board of Trade Returns.

Reference should here be made to the practice of continuing the use of a crank axle after it is suspected, or has even shown a slight flaw. At the Penistone inquiry it was given in evidence that if a flaw was detected the crank and pair of wheels were scotched and fixed to the rails in the shop, and another pair of wheels run against the pair to be tested, and if they stood that test they were considered all right. The author has known many suspected cranks break when working fast trains, and at the present moment he knows of several "doubtful" ones which may be the cause of a disaster any minute. Major Marindin, in his report, stated, "It is manifest that the more frequently cranks are examined thoroughly, the greater probability there will be that growing flaws will be detected; he therefore recommended that the big ends should be taken down at the weekly examinations,

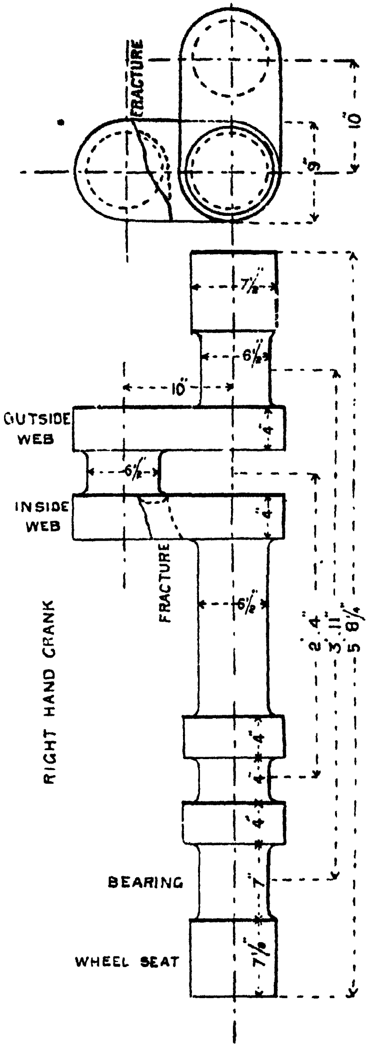


Fig. 29.—Crank Axle, Larbert Accident.

instead of only monthly, as at present; and as regards the Manchester, Sheffield, and Lincolnshire Railway Company, in particular, he observed that there must be considerable and unjustifiable risk in running a suspected axle under observation, when an apparent flaw has not been extended by the test to which it has been subjected, which, according to the evidence of the superintendent of the works at Gorton, was the practice upon that line." (July, 1884.)

On the 24th of August an accident was caused at Larbert Junction on the Caledonian and North British Railways by the breaking of the inside web of the right-hand crank of a Caledonian Company's tank engine, No. 541 (Fig. 29), when working the 10.15 p m. passenger train from Larbert to Grangemouth, the speed being about 15 miles an hour. The engine had six wheels, the leading and driving being coupled; a single frame and single bearings; the stroke was short, being only 20 inches.

The crank axle was of steel, made by the Bolton Iron and Steel Company, and its dimensions will be found upon the diagram. It had been working since November, 1870, and had run a total distance of 210,581 miles. It was not hooped. General Hutchinson in his report stated, "It is a grave question whether it is wise to continue to run crank axles after their mileage has reached a certain amount (to be fixed after careful consideration), especially in the case of steel axles, which often give such little warning before fracture."

The following table, compiled from the Board of Trade Returns, shows the total number of axles of all descriptions which have broken when running during the past eight years:—

Year.	Engine axles.		Tender axles.	Carriage axles.	Waggon axles.	Salt van axles.	Total.
	Crank or driving.	Leading or trailing.					
1878	266	21	19	3	221	10	540
1879	248	24	23	3	190	8	496
1880	251	27	25	1	192	18	514
1881	262	21	37	3	200	17	540
1882	242	22	32	2	140	13	451
1883	247	28	21	2	141	11	450
1884	200	23	24	6	113	19	385
1885	190	31	17	4	130	5	377

It is sincerely to be hoped that Major Marindin's suggestion as to the careful consideration of this subject will receive every attention; and that, as a practical result, a more perfect crank axle will be employed, which, together with the universal adoption of a quickly-acting automatic continuous brake, will render the recurrence of such a terrible disaster as that which happened at Penistone impossible.

CHAPTER VI.

IMPROVED COUPLINGS FOR RAILWAY WAGGONS.

One of the most important matters discussed at the Annual Congress of the Amalgamated Society of Railway Servants, October, 1885, was the great necessity for some improved form of couplings upon goods and mineral waggons, in order to avoid the guards and shunters having to go between the vehicles to couple or uncouple them. During the year 1884, 130 men were killed and 1,305 injured whilst engaged in shunting operations, and during the last nine years 1,122 have been killed and 11,314 injured under similar circumstances. The railway companies have for years been asked to take steps to prevent this serious loss of life, but unfortunately nothing was done to test the various appliances. The Servants' Society, however, at the Congress voted the sum of £500 to carry out the required practical trials. The experiments took place at the Nine Elms goods yard of the London and South-Western Railway, and, as the author was one of the judges upon that occasion, a copy of the report is appended:—

REPORT AND AWARDS

OF THE

JURORS OF THE COUPLING TRIALS,

Held at the Nine Elms Goods Yard of the London and South-Western Railway,

ON MARCH 29TH, 30TH, AND 31ST, 1886.

To the President and Members of the Amalgamated Society.

GENTLEMEN,

It will be remembered that at the annual general meeting of the Society, held at Leicester in October, 1885, a report was received from a committee appointed to examine the railway safety appliances at the Inventions Exhibition. In that report the committee stated that "no reliable report as to the efficiency of any system of coupling or uncoupling could be based upon the results of experiments with models alone. Nothing short of a trial with the full-sized and actual working appliances could be relied on, and they considered it of the utmost importance that a test of this kind should be arranged." Acting on this suggestion, the annual general meeting decided to set aside £500 for the purpose of offering prizes to inventors and to meet the necessary expenses, and instructed the executive committee to make what arrangements were possible for practically testing full-sized improved couplings. Such is a brief outline of the coupling question as it existed at the time of your last annual general meeting.

We now beg to report that, in pursuance of the foregoing instructions, we have instituted, carried out, and brought such trials to a highly satisfactory conclusion. In order to arrive at such a result, it was necessary in the first place to obtain the use of sidings, waggons, and an engine; and as soon as our requirements were made known through the press, Mr. Charles Scotter, general manager of the London and South-Western Railway, courteously invited two of the Society's officers to meet him at the Waterloo Bridge Station, so that he might know the extent of our requirements. Accordingly, on the 8th of January, an interview took place between Mr. C. Scotter, general manager, and Mr. J. T. Haddow, goods manager of the London and South-Western Railway, and Mr. Clement E. Stretton, C.E., vice-president and consulting engineer, and Mr. E. Harford, general secretary, on behalf of your society; when Mr. Scotter at once offered every facility that could be desired, and expressed a hope that the trials might result in practical benefit. It was also arranged that the trials should take place at the Nine Elms goods yard, as by its proximity to London, and its extensive siding accommodation, it presented a most suitable area for conducting such experiments.

On the 13th of January, 1886, a circular was issued to inventors by the general secretary, requesting those desirous of competing to forward drawings, specifications, or models of couplings they desired to have tested, to the head offices of the Society before January 30th. In response to that circular upwards of three hundred inventions were submitted for inspection, very many of which were crude and clearly unpractical, but, after careful examination by a sub-committee appointed for

that purpose, it reported that thirty-four of the appliances appeared to possess merit, and deserved to be entered for trial.

At the meeting of the executive committee in February, 1885, it was resolved that the jury to decide the relative merits of the couplings selected for trial should consist of thirteen members of that committee (who were at liberty to send substitutes in the event of not attending themselves) and three independent experts, viz., Mr. Clement E. Stretton, C.E., Mr. Lawrence Saunders, and Mr. Joseph Stevenson. This jury, as constituted, consisted of nine goods guards, two engine-drivers, one fireman, a signalman (who had previously been a shunter), and the experts just mentioned. It was further decided to offer three prizes for automatic and three for non-automatic couplings, of £100, £50, and £25 respectively, and to issue the following conditions, in order that inventors might understand the objects to be attained.

Non-automatic Coupling.

1. The operations of coupling and uncoupling must be performed quickly and with ease on either side of the waggon.

2. The apparatus should be equally efficient for coupling or uncoupling with a waggon fitted with ordinary hook and links.

3. Accidental uncoupling must be impossible.

4. If the apparatus should be out of order it must be possible to couple or uncouple the waggons as at present.

5. There must not be any projection at the sides or otherwise, with which the men might be accidentally struck.

6. The present drawbar hook should not be disturbed.

7. The parts must be capable of rough usage, and not liable to get out of order.

Automatic Coupling.

1. It must be possible to couple two or more waggons instantaneously on coming in contact with each other, and without the assistance of the shunters.

2. It must not be possible for waggons to couple on coming in contact with each other unless required to do so.

3. It must not be possible to uncouple accidentally.

4. The operation of uncoupling must be performed with quickness and ease on either side of the waggon.

5. It must be possible to couple easily with a waggon fitted with the ordinary drawbar hook and links.

6. It must couple or uncouple, if required, on curves.

7. The links or shackles must be flexible, and admit of waggons running together without the possibility of uncoupling.

8. The flexibility of the present links must be provided for to prevent accidents or injury to the apparatus or otherwise from rigid projections or parts.

9. There must not be any projections whatever, liable to cause accident or injury to shunters.

10. The apparatus as a whole must be strong, durable, and reliable.

11. The operation of putting the apparatus in position to couple, as also the operation of uncoupling, must be possible with one hand.

The following inventors submitted their couplings for trial:—Messrs. Younghusband and Hudson, of Darlington; Messrs. Wass and Wheeler, of Oldbury; Mr. W. Hill, of Stoke-on-Trent; Mr. R. Lansdale, of Halewood, near Liverpool; Mr. S. Pettit, of Kingston-on-Thames; Mr. C. Wroot, of Hitchin; Messrs. Morris and Wood, of Doncaster; Messrs. W. Cook and Sons, Glasgow and Sheffield; Mr. J. Royston, of Accrington; Messrs. Latham Brothers, of Sheffield; Mr. J. Davies, of Salford; Mr. J. T. Roe, of Balham; Mr. G. Turner, of Ashton-under-Lyne; Messrs. Beddall and Small, of Openshaw; Mr. J. H. Betteley, of London; Mr. W. H. Moon, of Swindon; Messrs. Attock and Morris, and Attock and Mosley (2), of Newton Heath; Mr. G. Fenwick, of Gateshead; Mr. T. Williams, of Stockton-on-Tees; Messrs. Mitchell Brothers, of Keighley; Mr. J. W. Hancock, of Leicester; Mr. C. B. Phillips, of Chester; Messrs. Ibbotson Brothers, of Sheffield; Messrs. Richardson and Greenwood, of Harrogate; Mr. W. Boucher, of Bullo Pill; The Hannay-Cowan Coupling Co., of Glasgow; Darling's Patent Automatic Coupling Co., of Glasgow; Mr. E. Heinke, of Upper Teddington; Mr. F. W. Trewhitt, of Barrow-in-Furness; Messrs. Holt and Whittaker, of Newlay, near Leeds; Mr. H. Stephens, of Beighton, near Sheffield; Messrs. Golightly and Son, of Guide Bridge; and the Compagnie des Appareils Automatiques, of Paris.

Of these inventions seven belonged to the automatic class, and twenty-seven to the non-automatic class. The automatic couplings, as their name implies, couple themselves when the waggons come in contact, and are put out of action when not required to couple. The

non-automatic couplings consist of various forms of links or chains, which are placed upon the drawbar hook of the next vehicle by means of various kinds of apparatus designed by the inventors for this purpose.

The methods adopted for testing the capabilities of the various couplings were of a decidedly practical character, and such as suggested themselves from our experience of every-day working of goods and mineral traffic on railways, which enabled us to form what we consider an accurate judgment of the merits and defects of each.

The result of the tests applied on the two first days was the selection of thirteen of the best inventions, for final test or consideration. Several of these possessed considerable merit, consequently the most close examination of minute points was made in order to determine their relative value, and it is worthy of notice, as a fact that adds greatly to the interest and value of these trials, that the voting in favour of these inventions, to which we have awarded the six prizes, was almost unanimous.

The following are our awards:—

NON-AUTOMATIC COUPLINGS.

1st prize of £100—Messrs. Younghusband & Hudson, of Darlington.
2nd ,, £50—Mr. W. Hill, of Stoke-on-Trent.
3rd ,, £25—Messrs. William Cook and Sons, Glasgow and Sheffield.

AUTOMATIC COUPLINGS.

1st prize of £100—Darling's Patent Automatic Coupling Co., Glasgow.
2nd ,, £50—Messrs. Latham Brothers, of Sheffield.
3rd ,, £25—Compagnie des Appareils Automatiques, of Paris.

With regard to the unsuccessful competitors, it is only fair to observe that some of their inventions had

points of merit that carry with them their own recommendation, while the points in which they failed might possibly be remedied, so that we take this opportunity of pointing out the defects observable in some of them which would be prejudicial to their adoption :—

1st. Rigid projections at the ends of the waggons, rendering them liable to injury by fouling other waggons. Also risk of injury to persons operating, through levers being awkwardly placed at the side of the waggons.

2nd. The position of the apparatus being so high as to interfere with sheeting, and not being adapted to low-sided waggons.

3rd. Not being adapted to couple when the drawbar hooks are in close proximity to each other nor suited to the varied length of buffers.

4th. Apparatus not adapted to fit coupling chains at present in use, in some cases alteration of a hook being also required.

5th. Levers so placed as to prevent shunters seeing the coupling when operating it.

6th. Failure to couple with certainty when applied.

7th. The apparatus being too heavy to work easily, some exceedingly so.

8th. Requiring practice or "knack" before they can be handled efficiently.

9th. Danger of damaging apparatus when placed in coupling position on waggons with spring buffers coming sharply together.

In conclusion, we beg to congratulate the Society upon the highly satisfactory termination to which the coupling trials have been brought, and the large amount of public interest they called forth. Never since the great brake trials at Newark in 1875 has such a

concourse of directors, officials, inventors, engineers, and railway servants been collected together to witness the carrying out of a trial of safety appliances, and it is certainly the first occasion upon which any railway company has ever placed a portion of its lines, rolling stock, engine and servants, for the time, entirely under the control of any Society, or person, and we hereby express our high appreciation of the courtesy shown to us, and the ample facilities afforded by the directors and general manager of the London and South-Western Railway. Finally,* we are of opinion that the appliances to which upon their merits we have awarded prizes are good, *practical, and inexpensive*† couplings, *which appear to fulfil all that can be required in daily working,*‡ and we have no hesitation in stating that their adoption would for ever terminate that fearful slaughter which annually results from goods guards and shunters having to pass between the waggons to couple and uncouple them, and which is so much deplored by the members of this Society, and the railway service generally.

We have the honour to be, gentlemen,
Your obedient servants,

Clement E. Stretton,	J. Buckley,
Lawrence Saunders,	Bernard C. Starkey,
J. Stephenson,	Henry C. Mady,
Johnson Flintham,	H. Davies,
James Jenkins,	T. Bevan,

* J. Stephenson dissents from the first clause, commencing at the word "finally."

† J. Easton objects to the words, "practical and inexpensive."

‡ W. Elliss objects to the words, "which appear to fulfil all that can be required in daily working."

CHARLES WRIGHT, W. ELLISS,
ED. GARRITY, WILLIAM FOREMAN,
FRED. WILLIS, J. EASTON,

EDWD. HARFORD, *General Secretary.*

Head Offices, Amalgamated Society of
Railway Servants,
306, City Road, London, E.C.
May 11*th*, 1886

DESCRIPTIONS OF THE SIX PRIZE COUPLINGS.

THE COUPLING OF MESSRS. YOUNGHUSBAND AND HUDSON, DARLINGTON.

1*st prize, non-automatic,* £100 (Fig. 30).

This coupling and uncoupling appliance is a very simple contrivance, and is especially designed to take hold of and utilise the existing links and hooks on railway waggons without any alteration to the same. By a simple combination of swivel joint and lever, every possible kind of movement can be given to the links by taking hold of the outside lever, which projects no farther than the outside of the buffer beam of the waggon, and from the great power a man has with the lever, it is well adapted to couple and uncouple stiff couplings. An idea of the facility of the arrangement will be gained from the fact that the time occupied to couple and uncouple a waggon is only two seconds. The weight of the coupling is 36 lbs. for each end of the waggon, and can be supplied at a cost

of 10s. for each end of waggon. This apparatus ca be made equally applicable to screw couplings as we as to chain couplings.

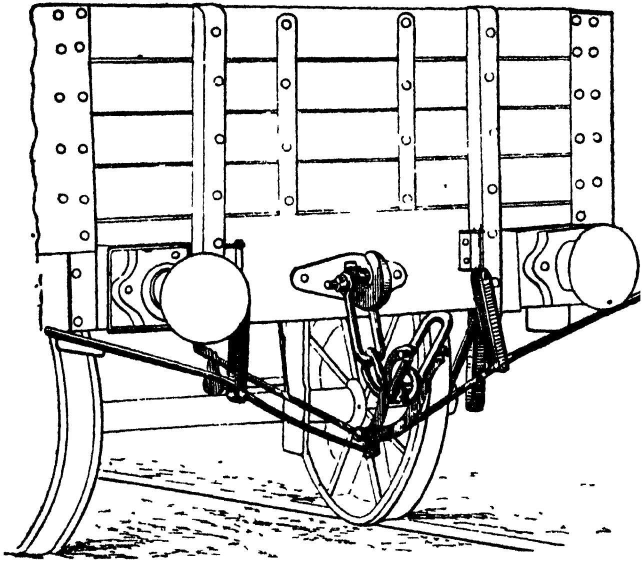


Fig. 30.—Younghusband and Hudson, Darlington (1st prize, non-automatic).

THE COUPLING OF W. HILL, STOKE-ON-TRENT.

2nd prize, non-automatic, £50 (Fig. 31).

To couple waggons lift the handle, which lifts the end link vertically to the height required for hooking on the other truck; on raising the handle a little higher, the end link travels laterally to the full length of chain; loose the handle, and end link drops over hook of the other waggon, and the work of coupling is complete. This arrangement is adapted for coupling

either full length of chain or as short as possible. To uncouple, raise the handle until the end link is high enough to miss point of hook, then loose the handle and the balance weight completes the work. Retains

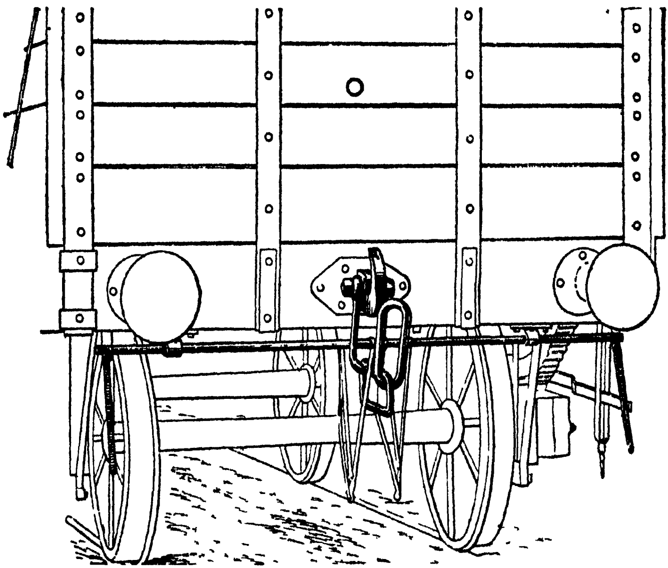


Fig. 31.—William Hill, Stoke-on-Trent (2nd prize, non-automatic).

the present drawbar and hook, and will couple with any present rolling-stock and stand rough usage.

The Coupling of W. Cook, Jun., Glasgow.

3rd prize, non-automatic, £25 (Fig. 32).

The operations of coupling and uncoupling can be performed quickly and with ease on either side of the waggon. The apparatus is fitted to the ordinary hook

and links. Accidental uncoupling must be impossible. If the apparatus should be out of order, it is possible to couple or uncouple the waggons as at present. There is not any projection at the sides with which the men might be accidentally struck. The present drawbar hook is not disturbed. The parts are capable of rough

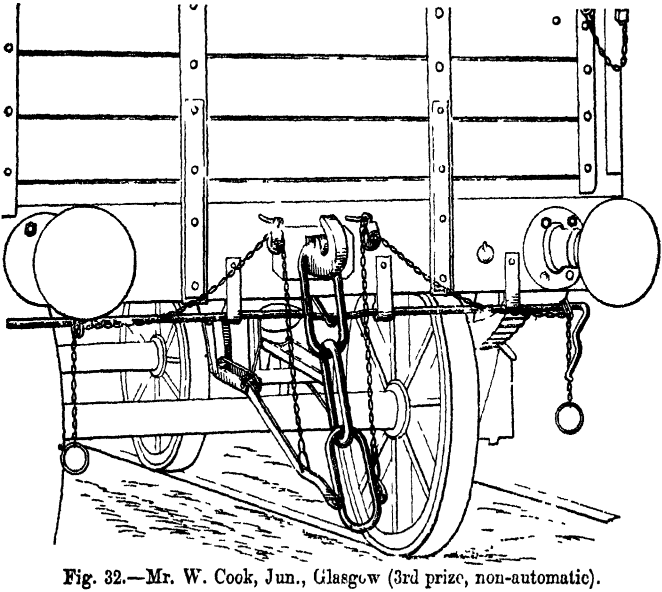


Fig. 32.—Mr. W. Cook, Jun., Glasgow (3rd prize, non-automatic).

usage, and not liable to get out of order. Will couple and uncouple with stone or coal waggons fitted with end doors for shipment. Will couple and uncouple with pig-iron and timber waggons, with no ends above trains. Will allow the tarpaulin to be fastened round buffers and ends of waggons without interfering with coupling apparatus. Will couple and uncouple on the

sharpest curves and with twisted drawbar hooks. Will couple and uncouple though the buffers be driven home and the drawbar hooks be only 2 inches apart. The inventor claims that it will couple and uncouple in the dark as well as in daylight. The apparatus will fit chains with or without shackles, and will couple with stiff shackles; also suits any length of chain or long or short links. The apparatus remains intact though the coupling chain should break.

Darling's Automatic Railway Coupling, Glasgow.

1st prize, automatic, £100 (Fig. 33).

The coupling is simple in construction, and combines with its simplicity all the requirements of an automatic coupling. One sees little that makes it different from an ordinary link coupling, while the link hanging loose on the opposing end proves that while flexibility is combined with necessary rigidity no new element of danger from projecting and absolutely rigid parts is introduced. The hook (which is practically the present drawbar hook modified to suit the needs of automatic action) is capable of assuming three or more different positions, and by a very simple arrangement automatically locks itself while in any of these positions. The coupling is by this means made to be perfectly reliable in the performance of the requirements of each position. In one position the links are horizontal, and the forward link sliding up the tail-piece of the opposing hook strikes a hood on the drawbar, and falls into the hook as if laid in by hand. The coupling has thus taken place automatically. This action of coupling has also relieved the back link from the support which renders

both links sufficiently rigid for coupling purposes. When it is desired to raise the links rigidly, the hook is yet further turned, when they are caught and held rigidly till put in the position for coupling; they are then coupled and rendered again flexible, as before described. According to the projection or recession of

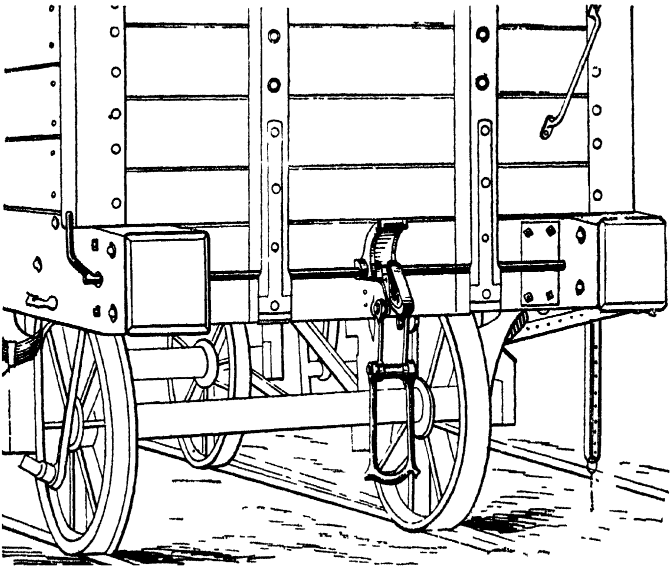


Fig. 33.—Darling's Coupling Co., Glasgow (1st prize, automatic).

the links, less or more tension can be had as desired, and the inside of the hook, being a radius of the centre on which it is turned, makes the uncoupling with ease a thing of course, and, in addition, has the advantage, when mixed with present stock, and the ordinary chain coupled on the hook of this coupling, the vehicles so coupled can be uncoupled from the outside; this in a

train of ten vehicles, five of which are fitted as at present, and five with this coupling, the whole can be uncoupled from the outside. The whole coupling has been called a *multum in parvo* and the advantages may be summarised as follow:—It couples two or more carriages instantaneously, as far as the buffers are compressed, by the ordinary means of running the carriages together; it uncouples instantaneously; it can be uncoupled when the train is in motion, or when the coupling is in tension, if desired; it can be uncoupled, or put in position for coupling, from either side or end of carriage, or from inside or outside of van; it is locked in position when coupled, and locked out of position when uncoupled; the driver can instantly uncouple his train or load; it is said to effect a great saving in time, and insures perfect immunity from danger during shunting operations, on account of coupling and uncoupling being performed without the necessity of any person going between the vehicles. It is believed that its cost will exceed but little the inefficient and dangerous coupling at present used; uncoupling and putting in position for coupling are of course done from either side or end of waggon or vehicle, and can be easily done with one hand.

The Coupling of Latham Brothers, Sheffield.

2nd prize, automatic, £50 (Fig. 34).

When two carriages, fitted with this coupling, are forced together, the higher link rides up the other, and a slight pressure on the buffers allows the link to drop automatically over the hook. The buffer springs then reassert themselves, thus making a perfect self-

coupling for carriages, with all the necessary tightening, &c., and entirely dispensing with manual assistance. For trucks the coupling is the same as for carriages (minus tightening apparatus), but longer in the link, to allow plenty of play when coupled, for curves, &c. For uncoupling, a pin passing through

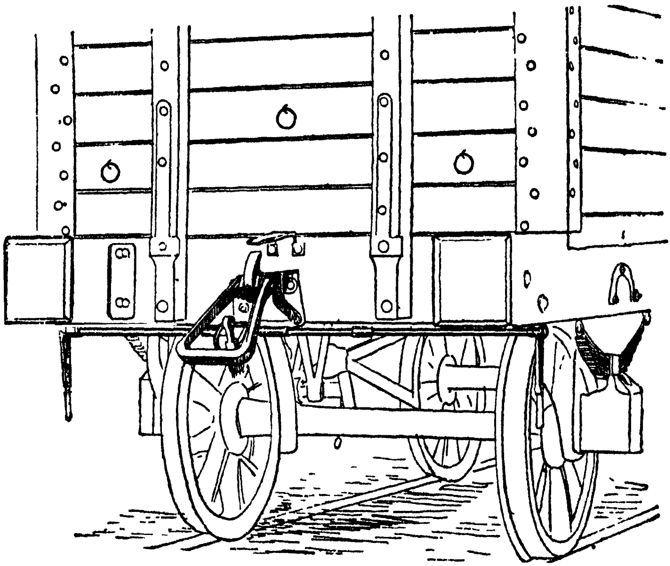


Fig. 34.—Messrs. Latham Brothers, Sheffield (2nd prize, automatic).

the drawbar and loose hook is easily withdrawn by raising the lever to which it is attached, allowing the hook to revolve on the shackle-pin, thus freeing the link. The instant the link is free, everything falls automatically into its place, ready for coupling again. As will be seen, this supplies a long-felt want, viz. a

perfect slip hook, invaluable for shunting of every description, as it can be uncoupled in any position. For fly shunting, where vehicles are required to be together without being coupled, the automatic link can be thrown back, or by hooking the side lever up, which withdraws the lock-pin.

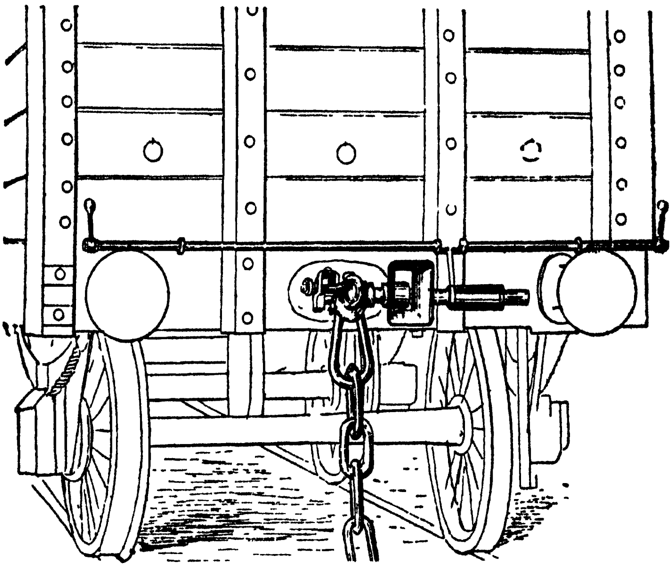


Fig. 35.—Compagnie des Appareils Automatiques, Paris (3rd prize, automatic).

The Coupling of the Compagnie des Appareils Automatiques, Paris (Fig. 35).

3rd prize, automatic, £25.

It is said this automatic coupling is not the first idea of an inventor, but the result of five years' continual

study and experiment. The inventor claims this coupling fulfils the following conditions:—It is possible to couple two or more waggons instantaneously on coming in contact with each other, and without the assistance of the shunters. It is not possible for waggons to couple on coming in contact with each other unless required to do so. It is not possible to uncouple accidentally. The operation of uncoupling is performed with quickness and ease on either side of the waggon. It is possible to couple easily with a waggon fitted with the ordinary drawbar, hook, and links. It couples or uncouples, if required, on curves. The links or shackles are flexible, and admit of waggons running together without the possibility of uncoupling. The flexibility of the present link is provided for, to prevent accidents or injury to the apparatus, or otherwise from rigid projections or parts. There are no projections whatever liable to cause accident or injury to shunters. The apparatus, as a whole, is strong, durable, and reliable; it has been tested at a strain of 50 tons, whereas the ordinary hook and chain are usually tested at 30 tons. The operation of putting the apparatus in position to couple, as also the operation of uncoupling, is possible with one hand. It can couple with a difference of 8 inches in height between the buffers. This coupling can be adapted to any existing waggons without requiring any alteration whatever in the rolling-stock.

CHAPTER VII.

RAILWAY SERVANTS AND THE LAW.

THE safe or dangerous way in which a railway is worked not only affects the lives and limbs of the railway servants, but it has another very serious aspect—namely, the law of manslaughter, and the very uncertain manner in which that law is administered.

Accidents constantly occur through the defective system of working adopted by the companies; but, unfortunately, whatever the system, when an accident causes the death of a person, the railway servants are liable to a charge of manslaughter; and the most important work which the Amalgamated Society performs is the legal defence of its members against the improper or unjust administration of the law in such cases.

There can be no question that the duties which railway servants have to perform are of such a nature that a momentary error may cause a serious accident, and it cannot therefore be too strongly urged upon them to take every care to provide for the safety of the traffic so far as lies in their power.

For many years it was quite usual to commit railway servants to prison unjustly, and it must be a

source of the greatest regret to every honest person to know that in very many instances the unfortunate men actually served long terms of imprisonment simply because juries did not understand the practical working of railways; they appeared to consider that as some person had been killed by an accident that it was part of their duty to see that some railway servant was blamed, or punished for manslaughter. This was a very easy and quick way of concluding an inquest or trial, but it was neither according to law nor justice, and certainly must not be permitted in the present day.

In Scotland, sheriffs and other authorities appear still to be of the old opinion that the best way to prevent railway accidents is to punish the servants; but it is perfectly well known that the only true policy for the prevention of what are called "accidents" is to adopt a proper system of working and the use of efficient brakes and other appliances to insure safety.

It has always been the custom whenever an accident happens for the companies to at once try to place *all the blame* upon some servant, in order that he may be punished, and that the responsible officers who are really to blame for neglecting to provide proper appliances may escape scot free. This very unjust practice has been most strongly condemned by both public opinion and the press. Fortunately, cases of unjust imprisonment have now been reduced to a minimum, and this happy result is mainly due to the persistent efforts of the Amalgamated Society of Railway Servants.

This one fact shows more clearly than words the

necessity which exists for a legal defence fund, and also the very great advantages which have accrued to members from the efficient way in which this fund has been employed to provide legal defence and obtain justice in such cases.

On the 31st August, 1878, a collision took place at Sittingbourne, on the London, Chatham, and Dover Railway, in consequence of part of a goods train being turned across the path of a passenger train by the mistake of a guard. The points were not interlocked nor worked from a signal-box, nor was the passenger train fitted with continuous brakes. Both the goods guards were tried for manslaughter, but were found "Not Guilty."

A serious collision occurred at Burscough Junction, on 15th January, 1880, in consequence of a signalman mistaking the position of a lever in his box. He was tried for manslaughter. The law was clearly laid down in this case, and is here quoted for further use upon any future occasion. Lord Coleridge explained the law of manslaughter, and stated that "the collision was the result of an *innocent mistake*, not through a criminal act which merited imprisonment;" and the signalman was acquitted.

The Rutherglen accident is one to which special attention should be directed. On the 24th January, 1880, an express train came into collision with another train standing at Rutherglen Station upon the Caledonian Railway, chiefly in consequence of the Clark and Webb chain brake *failing to act when required.* Although no person was killed, the driver, William McCulloch (who had for thirty-three years held an unimpeachable character of carefulness, attention to duty, and sobriety),

was tried before Mr. Sheriff Lees, at Glasgow, on a charge of "Neglect of duty."

The sheriff placed very great stress upon the fact that the train was "fitted with a brake which was happily characterised as an emergency brake," but he entirely omitted to take into his consideration that just upon the emergency the chain brake failed to act when the driver, in the performance of his duty, tried to apply it. At the conclusion of the case Mr. Sheriff Lees addressed the driver thus:—"I feel sure I should be utterly wanting in my duty as guarding the safety of the public, if I treated the offence of which you have been guilty, wilfully, on this occasion, as one that can be fitly punished by the imposition of any pecuniary fine, or any sentence of imprisonment short of one which will deter others from committing the offence in all times coming. I consider I am treating you with as great leniency as possible when I make your sentence one of four months' imprisonment."

Such a gross miscarriage of justice could not be permitted to pass unchallenged; the author, therefore, brought the facts under the notice of the Home Secretary, and a question was afterwards asked in the House of Commons by Mr. Stewart Macliver, M.P., president of the A.S.R.S. The following letter was forwarded to the author, copies of which appeared in the engineering papers at the time:—

[*Copy.*]

$\frac{93,498}{7}$ WHITEHALL,
26th May, 1880.

SIR,—The Secretary of State for the Home Department having considered your application in behalf of

William McCulloch, I have the satisfaction to acquaint you that he has felt warranted under all the circumstances in advising her Majesty to commute this prisoner's sentence of four months' imprisonment to one of two months' imprisonment.

I am, sir, your obedient servant,

(*Signed*) A. F. O. LIDDELL.

Mr. C. E. STRETTON,
Saxe-Coburg Street, Leicester.

The advocates of the chain brake did their utmost to prevent the release of the driver, and one of them even went so far as to say "he would sooner see a driver in prison for ever than damage the reputation of this brake."

The *Engineer*, commenting upon this case, remarked that "the least that could be expected was that the Caledonian Railway Company would replace the driver when he was released from his unjust imprisonment." But the author received official information that this was not the course intended; he therefore communicated with the chairman of the company, from whom the following reply was received:—

[*Copy.*]

CALEDONIAN RAILWAY COMPANY,
SECRETARY'S OFFICE,
Glasgow, 8th June, 1880.

SIR,—I have received your letter of yesterday's date, and beg leave to reply that although, when McCulloch is released, we shall not be justified in reinstating him as an engine-driver, we shall be prepared to consider

favourably any application he may make to us for other employment.—I am, sir, yours faithfully,

THOS. HILL.

CLEMENT E. STRETTON, Esq.,
Saxe-Coburg Street, Leicester.

It was satisfactory to find from this letter that the object of those who would have utterly ruined this most unfortunate man had been defeated, but so long as the "other employment" referred to was to be at a lower rate of wages than that of an express driver, it could not be considered that "justice" had been done. Ultimately, however, after very considerable correspondence, this unfortunate servant was reinstated as an engine-driver.

Since this accident the chain brake has, by its frequent dangerous failures, "damaged its own reputation" to such an extent that the Caledonian Railway Company has adopted a safe system complying with the conditions of the Board of Trade, and even the London and North-Western Company has discarded it, thus showing still more clearly the great injustice of McCulloch's sentence.

On the 8th September, 1880, a collision occurred at Penilee, on the Glasgow and Paisley Joint Railway, in consequence of the mistake of a signalman, but Major Marindin's report proved that if electrically interlocked signals had been in use the accident could not have been brought about by the mistake of this signalman; however, he was committed to take his trial upon the charge of culpable homicide, but was found "Not Guilty."

In the Prestbury case, which took place on the London and North-Western Railway, 3rd November,

1880, an engine-driver was committed for manslaughter, but the cause of the collision was that the distant signal failed to go "on" when required, and that the engine had no brake on its wheels. When the case came before the grand jury at Chester Assizes there was not even evidence enough upon which to find a "true bill," and the driver was consequently acquitted, without being put to the further trouble and expense of a trial.

A collision between two passenger trains took place at the Midland Station, Leeds, 21st December, 1880. It was due partly to the peculiar construction of the station, to the use of hand signals, and the mistakes of servants. The signalman and two shunters were committed for manslaughter. These men were not members of the Amalgamated Society, and had, of course, no private means for legal defence. A public subscription was raised for this purpose. The author was professionally engaged, both on behalf of the friends of the railway servants and the friends of the deceased persons killed in the collision.

At the Leeds Assizes (February, 1881) Mr. Justice Manisty pointed out that "there are very different degrees of negligence. An error of judgment, a simple mistake, or an accident is not sufficient to sustain an indictment of manslaughter. Before such a verdict can be returned, it is necessary that the negligence shall be of that serious character known as gross, culpable, or criminal negligence," and he considered the case against the prisoners as far too remote, and they were acquitted. In the Desford Junction case (22nd October, 1881) it was clearly shown that the verdict of the coroner's jury contained in a rider such severe

censure upon the company that, as the *Engineer* remarked, "it closely resembled a verdict of manslaughter against the responsible officers." The signalman omitted to place the points in the proper position, but such facing-points leading from a passenger line into a siding should never have been allowed to exist; they have since been removed. Instructions for the working of traffic "when the signal and interlocking arrangements are defective" have been issued, and the passenger trains have since been worked with continuous brakes.

At Tayport a collision occurred on 25th November, 1881. The signalman was arrested and kept in Cupar Prison for a week, and the guard for a few days, although bail to any required amount was forthcoming; however, when the Procurator-Fiscal found that the matter was receiving great attention in the engineering papers, and that a question was about to be asked in the House of Commons, he granted bail. At the trial it came out that the signalman was over sixty years of age, that he had been in the service and borne an excellent character for more than thirty years, and that he was kept on duty daily for from 15½ to 16 hours; at the end of one of these long days he made a mistake and caused a fatal collision.

Major Marindin stated in his report that "it is hardly too much to say that it is a scandal that such an amount of work as is implied by these hours should be exacted from any man upon whose vigilance depends the safety of the public."

During a severe snow-storm a collision took place at Mennock Sidings, on the Glasgow and South-Western Railway, 7th December, 1882. An express train was stopped by signals at Sanquhar, but the two drivers

started from that station on receiving verbal instructions from a man (afterwards found to be a clerk sent by the station-master), and a collision with a goods train followed. Both drivers and the station-master were committed for "Culpable Homicide." At the trial the charge against the drivers was abandoned, and the jury found the station-master "Not Guilty."

On the 11th December, 1882, a collision took place at Dinting, during a storm which had blown down the telegraph wires and destroyed the block system. The signalman was committed for manslaughter on the coroner's warrant, but was not taken before a magistrate. At the trial the judge asked, "What were the printed instructions of the prisoner?" As they could not be produced in court, he held that "it could not be proved that the prisoner had violated any of the company's rules; as it could not be proved what his duties were, how could it be said that he had not acted up to them?" A formal verdict of "Not Guilty" was at once returned, and it was then shown that if any one was to blame it was a person totally different from the signalman. His lordship said, looking at that fact, and also that an irregular course had been adopted in not taking the case before a magistrate, he should disallow the costs of the prosecution.

In the Blackwell case, on the Midland Railway, 19th January, 1883, a signalman had his attention suddenly called to the telegraph instrument, and forgot for a moment that a "light engine" was standing near his box; a clerk authorised to be in the signal-box was stated to have given the signal for another train to approach. The signalman was tried for manslaughter, but acquitted.

A serious collision between two passenger trains took place at Eglinton Street, Glasgow, on the Caledonian Railway, March 19th, 1883. The cause of the accident was that the driver of one train started and ran past a signal at danger. He had only been in the company's service two months, having entered at the time of the *strike*. He stated that "in momentary forgetfulness he overlooked the signal." He was committed for trial on a charge of "Culpable Homicide," and admitted to bail. At the trial, however, he did not appear, and was accordingly *outlawed*. This driver thought he knew the road and signals, but the facts show that he did not; this was an error of judgment, not a criminal act.

Another case which requires attention is the disaster which occurred on the Caledonian Railway at Lockerbie, 14th May, 1883. A branch passenger train ran past the signals, came into collision with a goods train, knocking at least one waggon foul of the up main line, upon which the up west coast mail was approaching at full speed. The driver and fireman of the leading engine of the mail and five passengers were killed, a very large number being injured. The Caledonian Railway Company had erected a signal on the branch *after* the arrangements had been inspected and approved by the Board of Trade; and Major Marindin's report stated that this "was a grave error of judgment on the part of the company." The station-master introduced a dangerous system of working trains to the wrong platform on the wrong line, which thus compelled drivers to pass danger signals when they received hand signals. The traffic inspector actually knew of this dangerous working, but took no steps to put a stop

to it. The branch train was not fitted with continuous brakes, or the driver could easily have stopped and avoided the first collision, and of course the disaster which resulted; and if the up mail train had been provided with a proper brake it could have been stopped from a speed of 50 miles an hour in much less than 360 yards. The Scotch authorities did not appear to have taken all these points into their consideration, but simply committed the station-master and the branch driver for "Culpable Homicide." The charge against the station-master was abandoned; the driver was tried at Dumfries, but the jury returned a verdict of "Not Guilty." This result was satisfactory; but still it appeared very hard that a driver should be arrested and subjected to all the trouble and expense of a trial for manslaughter, when from the very first it might have been clear to every one that there was no evidence to sustain such a serious charge.

On the 28th July, 1883, an east coast train from Edinburgh was standing at the ticket platform, Caledonian Railway, Perth, when it was run into by a west coast express from Euston. This latter train was fitted with the Clark and Webb chain brake. This apparatus failed to act when required, and thus caused the collision, which resulted in the death of one person and injury to seven others. The engine-driver was arrested, and charged at the Perth Police Court with "Culpable Neglect of Duty." Two days' examination failed to produce any evidence in support of the charge; but instead of the driver having the benefit of any doubt he was committed for trial to the sheriff. He was, however, ultimately found "Not Guilty."

An up London and North-Western express train

came into collision at Watford on the 31st October, 1883, with some carriages left standing on the main line. The accident was due to the forgetfulness of the signalman, but the practice of shunting carriages from one main line to another in order to clear another line was most objectionable and dangerous, unless means are adopted to make it mechanically impossible for such a mistake to be made. The signalman was arrested and charged before a magistrate with manslaughter. This charge, however, could not be proceeded with as the coroner's jury returned a verdict of "Accidental Death," and added to it a presentment, "that the known good character which the signalman bore, and the length of time he had been in the service, lead them to the opinion that his aim was to do his duty faithfully, and they should be pleased to see him reinstated in the service of the company."

A collision occurred at Rufford Station, on the Lancashire and Yorkshire Railway, 2nd January, 1884. This station was not provided with the necessary refuge siding, and in consequence it was the usual practice to shunt goods trains across from one main line to the other in order to allow passenger trains to pass; and on this occasion a goods train, which had been crossed over, was run into by another goods train, which could not be stopped in time. General Hutchinson pointed out in his report that the collision would not have occurred if there had been the necessary siding, and it would also have been prevented had the block system been in force as regards goods trains. He pointed out that if the goods traffic on the line was too thick to allow of the block system being carried out as regards goods trains, it would at any rate seem

desirable and practicable that the driver of a goods train should be informed at the previous station whether or not the line is clear. The collision caused the death of a goods guard, and the engine-driver, a member of the Accrington Branch of the A.S.R.S., was committed for manslaughter, but at the Lancaster Assizes a verdict of "Not Guilty," was returned.

On the 7th June, 1884, a serious collision occurred at Sevenoaks, on the South-Eastern Railway, between two goods trains, by which an engine-driver and fireman lost their lives. The accident was due to a mistake in working the block system. The signalmen at each end of the section were both men bearing excellent characters, and both gave their evidence in a straightforward manner. The signalman at Hildenborough appears to have made the principal error, and on that account the jury returned a verdict of "Manslaughter" against him, but at the Assizes he was found "Not Guilty." Major Marindin, in his report upon this case, stated "it was more than probable that this accident would never have taken place if there had been a separate and distinct plunger for giving bell signals according to the code," and he pointed out that the effective interlocking of the block instruments with the out-of-door signals effectually prevents collisions of this description arising from a signalman's mistake.

On the 7th July, 1884, an accident took place at Wilmslow, on the London and North-Western Railway, near Manchester. The circumstances appear to have been very similar to those attending an accident which occurred at Prestbury, November, 1880. It is the usual practice at Longsight to run express engines for a trial trip after repairs, the foreman fitter riding upon

them to watch the working, and on the occasion in question engine No. 1,513 was being tested without a train at a speed of 60 miles an hour. The Handforth signals were "off," but the Wilmslow signals "on." The driver attempted to apply the "Webb steam brake," but it failed to act. A collision followed, and the foreman fitter was killed. At the inquest Mr. Whale, the company's assistant locomotive superintendent, stated that 60 *miles an hour was an improper speed*, and that even when the brake had failed, if the driver had reversed his engine he could have stopped from 60 miles an hour in 300 to 350 yards. This latter statement was perfectly untrue, but upon Mr. Whale's assertions the jury returned a verdict of "Manslaughter" against the engine-driver. When, however, the jury afterwards found that they had been misled, no persons were more sorry than themselves that they should have returned a wrong verdict; and one juryman felt so strongly upon the point that he came to Leicester to ask the author to do his utmost to obtain justice at the trial, and to prevent the driver's committal before the magistrates. When the case came before the magistrates at Macclesfield they did not even require an answer to the charge, but dismissed it with the remark, "There is no case at all; not the slightest;" and at the Chester Assizes the author had the pleasure of being in court when the grand jury ignored the bill, and in accordance with the directions of the learned judge the jury at once returned a formal verdict of "Not Guilty," and the driver was set at liberty. In face of such facts as these it would have been but simple justice for the company to have reinstated this unfortunate driver in his former position, but instead of that he was

discharged from the service, after eleven years' work without a fault. The *reputation* of the steam brake could not under any circumstances be allowed to be damaged, so the driver was sacrificed to it.

On the 2nd April, 1885, a collision occurred between Roby and Edgehill, on the London and North-Western Railway. A goods train was stopped for some time at the Roby signal-box, waiting for the previous train to be signalled "clear," and by some error a "light engine" following, ran into the rear of the goods train, and the guard was shaken. Nothing further was heard of the matter till the 12th October, when the guard died; an inquest was held at Warrington, and a verdict of "Manslaughter" returned against the signalman and driver of the light engine. When the charge was investigated at the Prescot Petty Sessions, the medical evidence proved that the deceased died from consumption and pleurisy rather than from the effects of the railway collision. Why this fact was not discovered by the coroner's jury before the verdict of "Manslaughter" was returned is a question which was never explained, but it is clear that an injustice was done to the signalman and driver.

On the 13th May, 1885, two gangers were thrown from a ballast train and killed at Inchicore, Dublin, and a verdict of "Manslaughter" was returned against the engine-driver, it being alleged that the engine was started without the whistle being sounded. At the trial the evidence was insufficient to support the charge, and a verdict of "Not Guilty" was returned.

A serious collision occurred at Binegar Station, upon the Somerset and Dorset Joint Railway, upon the 31st July, 1885. In consequence of the interlocking gear

having been removed, and no man appointed to watch the facing-points, as required by Rule 149A, a passenger train was wrongly turned into a loop line, and came into collision with a goods train, and a passenger was killed. The true cause of the accident was that the company's rules were not carried out by the officials, as follows:—

"Rule 149A. When the interlocking of any lever frame, or any facing-point, bolt, or bar is out of order, or when any point or signal lever, or any home, starting, or advanced starting signal, or siding signal applicable to a siding not protected by safety points, is defective, and not working properly, one competent man, or more, as may be necessary, provided with hand signals and detonators, must be appointed to act under the instructions of the signalman in charge of the signal-box, and the distant signals applicable to the lines affected must be kept at danger by being disconnected from the levers by which they are worked, and must remain in that position until the defect has been made good, and all is again in working order.

"When the interlocking of a signal-box, or any facing-point, bolt, or bar is being altered or repaired, the fitter in charge of the work must give to the signalman in charge of such signal-box an exact statement of the signals and points which it will be necessary to work temporarily without the safeguard of the interlocking, or the facing-point, bolt, or bar."

At the inquest this rule was not produced, and in reply to a question as to "whether it was not necessary to take extra precautions by placing a man at the points," the superintendent of the line, stated on oath that "it was not." Upon that false evidence the sig-

nalman was committed for manslaughter. This was not a member of the Amalgamated Society of Railway Servants. The Leicester Branch, however, having heard the author's report upon the case, requested him to take up the matter, and obtain justice. Upon further examination of the facts and distances, the author found that the passenger train was not provided with proper brake power. If it had had a proper continuous brake it could have been stopped from a speed of 27 miles an hour in less than the available distance of 160 yards, and the collision would thereby have been avoided. The prisoner was also unjustly treated by the police authorities, who would not charge him in the usual course before the magistrates, thus preventing the author from producing the evidence as to facts. At the Bristol Assizes, the judge, Baron Pollock, in charging the grand jury, referred at length to the case. He said:—"The next case of manslaughter was against William Applebee, a railway servant on the Somerset and Dorset line, at Binegar Station. There were circumstances connected with this case on which he felt bound to make some remarks. Not until that morning did he receive the depositions in the case; they were lengthy, involving very peculiar facts—so peculiar, that unless a person was well versed in railway management it would be extremely difficult in such a short time to master the facts at all. He could not understand why the persons whose duty it was to lay the circumstances of such serious cases before the judge and jury had not in common decency sent the depositions long ago, so as to be put before him in proper form. That was not the only matter he had to complain of. These events took place so far back as August, when the

prisoner was apprehended on a warrant for manslaughter, issued by the coroner after the finding of his jury. It was thoroughly known to all the criminal authorities of this country, and had been laid down again and again by judges, that whenever a man was to be put on his trial it was the duty of those who did so to have him committed by a magistrate, before whom the evidence was taken, and who had far better means of inquiring into the case than a coroner's jury. That had been the long-established and universal rule. The course now adopted of sending a man for trial on the evidence taken before a jury led to this: In legal strictness a verdict of a coroner's jury was equivalent to the finding of a grand jury. Manifestly there was great inconvenience in sending a man to take his trial on that finding, because the judge and jury had not the means which they ought to have of seeing the case investigated before the magistrates, who would express their opinion by committing or discharging the accused, as they thought fit. In modern times they allowed the bill to go before a grand jury and take their opinion, and he would abide by that rule, and ask the grand jury to receive the evidence as if the man had been properly committed by a magistrate. Beyond doubt the poor woman, Annie Charles, lost her life by a collision which took place at Binegar Station in consequence of a train being sent, as it came through the station, on to the wrong rails—the down instead of the up line. The mechanical cause of the train being so sent was the points being wrongly placed, by reason of the prisoner, one of the pointsmen in the signal-box, moving bar No. 11 instead of No. 12. If that were an ordinary case the prisoner would stand almost without

defence, and the degree of negligence would be for the jury. On the present occasion, however, it seemed that some alterations were being made in the locking process and the signal arrangements of the station, to a certain extent under the supervision of the officers of the Board of Trade. Everything was done correctly and in order, but at the very time in question when prisoner moved the wrong bar a great portion of this machinery had been disconnected. No doubt if the prisoner had been properly instructed, and was aware of the exact condition of things as they existed, he could and ought, by using the proper handle, to have avoided this accident. But then came the important question of negligence, and they would require strict proof that there had been real criminal negligence. It was very important for all the public travelling by railway that the rules should be properly observed, and it was also important that men in the prisoner's position should not be unjustly punished for criminal negligence. He found that the person having the direction and carrying out of these alterations was not able to say distinctly that he called the prisoner's attention to what was going on. That person was in a superior position, and would understand the nature of the mechanism, and the result of the changes going on. It did not follow that the prisoner was guilty of negligence. The grand jury would have the evidence before them, and in relief of their mental labours he advised them to confine their attention mainly to what passed in the signal-box, so as to come to a fair conclusion about the extent of negligence, if any, of which the prisoner was guilty."

The grand jury ignored the bill, and desired to

express a strong opinion that there was great neglect on the part of the officials of the railway company in not giving prisoner the necessary notice, as required by the rules of the company, before the alterations commenced.

The prosecution then decided to offer no evidence on the coroner's inquisition, and the signalman was discharged. With reference to the way of conducting the case by the prosecution, his lordship informed their counsel "that it was not the proper mode of administering the criminal law of this country. In such a serious case that course was obviously unsatisfactory."

From the whole facts of the case it was from the first perfectly clear that a great injustice had been done to a railway servant, and it is to be hoped the remarks of the judge may lead coroners, juries, and police authorities to be far more careful in future.

A collision occurred at Coatbridge, on the North British Railway, on the 5th August, 1885. From the Board of Trade report it appeared that the fireman neglected to connect the continuous brake; the driver did not take the trouble to examine it; the guard did not keep a look-out, or he could have applied the brake from his van and stopped the train.

These three men were committed for trial on a charge of "Culpable Neglect of Duty," and the case came before Sheriff Mair and a jury at Airdrie Court. The driver and fireman were found "Guilty," judgment being that they should be "fined £10 each, or two months' imprisonment." The author is very glad to be able to point out that this is a very exceptional case, being the first throughout this list of accidents in which servants were guilty of "culpable neglect." Fortu-

nately, no person was killed, or the sentence might have been a very heavy one. The author examined the facts, and would have been glad if any excuse of extenuating circumstances could have been found to exist. Of course, no one can support or encourage those who are guilty of culpable neglect.

On the 4th November, 1885, a collision occurred at Bridge of Dun Station, upon the Caledonian Railway. Major Marindin reported that there was a serious breach of rules by the signalman, and gross neglect of duty on the part of the driver, fireman, and guard. The signalman and driver were, on the 12th January, 1886, tried at Forfar, before the sheriff and a jury, upon a charge of "Culpable Violation of Duty." The jury took a very lenient view of the case, and returned a verdict that the charge was "Not Proven."

A serious collision occurred at Binegar, on the Somerset and Dorset Joint Railway, on the 3rd February, 1886. Two goods trains met upon the single line.

Colonel Rich reported that "the greater portion of the Somerset and Dorset Railway consists of a single line of rails. It is worked, subject to an undertaking from the company, that only one engine in steam, or two or more engines coupled together, shall be allowed to be on any section of the single line at the same time; but instead of the engines being confined to particular sections, they are run all over the railway, the crossing of the engines and trains being managed by a telegraph clerk at Bath, who is specially employed for that purpose. This mode of working is not safe." . . . He recommends "that the mode of working the single-line portion of the Somerset and Dorset

lway should be altered to the train staff or tablet system."

The signalman was tried for manslaughter at Taunton Assizes, and sentenced by Mr. Justice Day to six months' hard labour. The Government Inspector clearly showed in his report that the system of working was very dangerous, and, in fact, was the true cause of the accident, and that the signalman was but the human being who fell or was led into the trap.

The sentence is so severe and the injustice so great, that the author felt justified in placing the facts before the Home Secretary, and he has the following reply :—

[*Copy.*]

X 10447. WHITEHALL, June 3rd, 1886.

SIR,—I am directed by the Secretary of State for the Home Department to acknowledge the receipt of your application in behalf of John Cox; and I am to acquaint you that the same will be fully considered.

I am, sir, your obedient servant,

GODFREY LUSHINGTON.

C. E. STRETTON, Esq.,

40, Saxe-Coburg Street, Leicester.

OVERWORK.

Overwork on railways is highly dangerous, both to the men and to the passengers. Ten hours a day of railway work, considering its importance, should be sufficient, and care should be taken that proper time for rest, say eight or nine hours, is allowed between each term of duty. Signalmen should not be called

upon to work more than eight hours at a stretch, and at very busy and large junctions, six hours is as much as should be required. It is not a question of how many hours a man can work, but of how many hours he can work traffic efficiently and safely; and any railway servant who has been on duty fifteen, eighteen, or twenty-four hours is not and cannot be in a fit condition to devote that sole attention to his work which its importance so much demands.

APPENDIX I.

RAILWAY TRAFFIC RETURNS.

The publication of the returns relating to railway capital, traffic, and working expenses, together with the statements of the chairmen at the half-yearly meetings, have once again directed special attention to the decline of first and second-class traffic, and the increase and wonderful development of the third class. It has been asserted by some writers that railways would have been gainers if the old system had been retained, and the third class left practically where it was ten or twelve years ago. Such arguments, and figures based upon them, are of little value, for railway companies, like individuals, must either progress with the times, or be left completely in the rear; and most certainly the companies which do the greatest good to the greatest number by every endeavour to promote and increase third-class traffic will receive their full share of reward and profit. For many years railway companies conveyed only first and second class passengers by fast trains, third-class passengers having to travel by slow trains, running at very inconvenient times, and composed of very uncomfortable carriages. Third-class traffic was therefore practically discouraged, and it was hoped that the third-class passengers would thus be forced to ride in carriages of a superior class

at higher fares. In practice, however, it was found that, although a small proportion of persons were thus compelled to ride "second class," a very large proportion were forced to stay at home and not travel at all. The folly and absurdity of this mistaken policy was well known to Sir James (then Mr.) Allport, of the Midland Railway, and upon April 1, 1872, that company conferred a very great boon upon the travelling public by attaching third-class carriages to all its trains at the parliamentary fare of one penny per mile. This change proved, in a very short time, that the third-class traffic, which had been for years "pushed on one side" and "discouraged," actually paid better than either the first or second classes, which had been specially accommodated and encouraged. The second-class traffic, however, was found to gradually decrease until January 1, 1875, when the Midland Company very wisely abolished that class, and were thus enabled by this means to take off the empty second-class carriages, which had become simply an additional dead weight upon the trains. The last improvement introduced on the Midland came into force November 1, 1883, when first-class passengers were allowed to ride in the Pullman drawing-room and dining cars *without* extra charge. The question has been asked, but not clearly answered, *Why the first class declines?* It must be remembered that at the time when first and second class flourished, third-class passengers were only conveyed in slow trains, therefore those who travelled in the higher classes not only paid for superior carriages, but for increased speed. Money thus laid out paid the passengers in the shape of time saved in travelling; but in these days the third-class passenger, very

properly, performs his journey by the same trains (there are exceptions upon some lines) and arrives at his destination as quickly as the higher classes. It will thus be seen that the first-class passenger does not now obtain any extra speed for his additional fare, and the question resolves itself simply into this: Will passengers pay two or three pence per mile to sit in a first-class carriage, when for one penny they can ride, perhaps, in the next compartment of the same vehicle? The decline of first-class traffic is the most conclusive answer that they will not, and there can be no doubt that either the first-class fares must very soon be lowered, or the empty first-class carriages now to be seen upon many lines must be taken off the trains, as they are fast becoming useless dead weight. The rapid decline of first-class traffic has for some time been referred to at half-yearly meetings, and a short time ago it will be remembered that Mr. Moon, at Euston, remarked, "We find that gentlemen of the first position take third-class tickets. All he hoped was they would have sweeps or navvies riding with them." The returns show that the cheap class forms the mainstay of the receipts, and there can be no question that the only true policy is to encourage and increase the third-class traffic. During the year 1884 the total capital shows an increase, the receipts a decrease, and 183 additional miles of line have to be worked, consequently a decline in dividend must be the result. The following tables give the summaries of the returns for the year 1884, and it will be noticed that even in the present depression of trade the third class shows an increase both in numbers and receipts.

The total receipts per train mile were a little over

4s. 11½d. (59·56), and the working expenses 2s. 7½d. (31·59), showing a net profit of nearly 2s. 4d. (27·97) per mile.

Mileage.	
Number of miles run by passenger trains	143,144,694
,, ,, goods and mineral trains	126,672,783
,, ,, mixed trains	2,985,743
Total	272,803,220

Passenger traffic.	Number of journeys.	Receipts.
First-class passengers	34,582,539	£3,481,017
Second-class ,,	62,225,220	3,105,008
Third-class ,,	598,144,101	17,606,040
Season tickets (766,691)	—	1,763,491
Excess luggage, mails, &c.	—	4,074,894
Total	694,991,860	£30,030,450

Goods traffic.	Weight in tons.	Receipts.
Goods traffic	75,712,330	£20,879,968
Mineral	183,615,556	15,528,656
Cattle, &c.	—	1,237,780
Miscellaneous	—	24,188
Total	259,327,886	£37,670,592

Miles open.	
Miles of railway open 31st December, 1883	18,681
,, ,, opened during year 1884	183
Total miles open 31st December, 1884	18,864

Number of locomotives	14,827 = increase 358
Number of passenger carriages	33,031 = increase 727
Number of vans, waggons, and all other vehicles (not including private traders' waggons)	479,695 = increase 21,338

Capital paid up and raised.		
Ordinary	£298,983,446	
Guaranteed	95,603,613	
Preferential	205,809,234	
Loans	14,793,420	
Debenture stock	186,274,654	
Total	£801,464,367	= increase of £16,543,055

Receipts.		
From passenger traffic .	£30,030,450 =	increase of £521,717
From goods traffic . .	37,670,592 =	decrease of 1,030,727
From miscellaneous traffic	2,821,601 =	decrease of 30,617
Total . .	£70,522,643 =	decrease of £539,627

Working expenses.	Total	Cost of working per train mile in pence.
Maintenance of way and works, &c.	£6,622,539	5·82
Locomotive power	9,465,793	8·35
Rolling stock	3,399,397	3·00
Traffic expenses	11,279,062	9·91
General charges	1,636,595	1·44
Rates and taxes	1,937,601	1·70
Government duty	398,577	0·36
Compensation for personal injuries	183,657	0·16
Compensation, damage, and loss of goods	202,400	0·18
Legal and parliamentary expenses .	323,990	0·29
Steamboat, canal, and harbour expenses	1,305,415	—
Miscellaneous . . .	461,798	0·41
Traffic expenditure not classified .	52,343	—
Total	£37,217,197*	31·59 = 2s. 7½d.

Total receipts as above . .	£70,522,643 =	decrease of	£539,627
Total working expenses as above	37,217,197 =	,,	151,365
Net profit therefore . . .	33,305,446 =	,,	388,262

Number of miles run by	passenger trains . .	increase	4,967,754
,, ,,	goods and mineral trains	decrease	1,310,470
,, ,,	mixed trains . . .	increase	248,700
Total increase			3,905,984

		Numbers.		Receipts.
First-class passengers . .	decrease	1,805,338	decrease	£189,036
Second-class ,, . .	,,	3,831,564	,,	224,736
Third-class ,, . .	increase	16,910,625	increase	555,976
Season tickets	,,	134,641	,,	70,900
Excess luggage, mails, &c.. .		—	,,	308,613

Passengers, three classes, increase 11,273,723 in numbers.

Goods, &c. . . .	decrease	1,185,026	tons
Mineral . .	,,	5,870,056	,,
Total decrease . .		7,055,082	,,

* Exclusive of £52,060 received by North London for working other lines, but included in above figures.

Attention should here be directed to a most important question, which must, at no very distant date, be practically considered. The author refers to the increase of train miles and the decrease in receipts per mile. With a decline in business it is certain that competition becomes much more severe, but it is a mistake to run useless mileage with certain trains simply for the sake of nominal competition. During the year 1884 the passenger mileage was increased no less than 4,967,754 miles. There is great reason to believe that a large portion of the extra working is due to the running of new trains, which do not pay half or even a quarter of the working expenses; indeed, the author has figures and proofs that there are trains running which do not average six passengers, and, as a rule, are composed of six vehicles. Again, in consequence of the number of empty first and second-class compartments on trains, the total weight is needlessly increased, often causing the running of two engines. The author is of opinion that by reducing the number of useless empty trains, and the removal of empty carriages from other trains, working expenses can be very considerably reduced without curtailing the accommodation given to the travelling public, and he has for a considerable time advocated the introduction of third-class dining and sleeping carriages. There can be no question that the company granting such a boon to the cheap class will very soon increase its receipts.

APPENDIX II.

RAILWAY SIGNAL RETURNS.

Since this volume has been in type the returns have been published relating to "signals" to the 31st December, 1885, and "continuous brakes" to 30th June, 1886, and to bring the work up to date the following Appendix is added :—

The Railway Signal Returns for 1885.

The return relating to the railway signal arrangements and systems of working on December 31st, 1885, has recently been issued by the Board of Trade, the details being, as usual, given under two headings : (1) The interlocking and concentration of signal and point levers; (2) The systems upon which the lines are worked, relating to the block system, &c.

The details are minute and voluminous, but the facts can be seen at a glance upon reference to the following tabulated statements. No. 1 shows that the levers require concentration in 4,993 cases, and interlocking in 4,770 instances; also that no less than 2,875 pairs of safety points are requisite. From table No. 2 it will be seen that the total length of line open for passenger traffic was 18,069 miles, of which 14,185 miles were worked on the absolute block system. There are 346 miles of single railway, upon which only one engine at one time, or two coupled together, are allowed; thus leaving a balance of 3,538 miles which are still worked

SUMMARY No. 1.

	Number of cases in which any passenger line is connected with or crossed on a level by—				Number of cases in which the usual requirements of the Inspecting Officers of the Board of Trade have or have not been complied with in the following respects:—					
—	Any other passenger line.	Any goods line.	Any siding.	Any cross-over road.	Concentration of signal and point levers.		Interlocking of signal and point levers.		Addition of safety points in cases of goods lines and sidings.	
					Have.	Have not.	Have.	Have not.	Have.	Have not.
England and Wales	3,973	1,367	17,543	6,670	26,734	2,819	26,938	2,616	17,316	1,594
Scotland	748	216	3,114	1,024	3,979	1,123	3,944	1,158	2,722	608
Ireland	393	84	1,226	277	929	1,051	983	997	637	673
Total: United Kingdom	5,114	1,667	21,883	7,971	31,642	4,993	31,865	4,770	20,675	2,875

SUMMARY No. 2.

—	Total length of railway opened for passenger traffic.		Distance worked on the absolute block system.	
	Double.	Single.	Double.	Single.
	Miles.	Miles.	Miles.	Miles.
England and Wales	8,545½	4,212¾	8,239¾	3,225
Scotland	1,146	1,644	1,109½	1,114
Ireland	589	1,933	169¼	327¾
United Kingdom	10,279½	7,789¾	9,518½	4,666¾
Total	18,069¼		14,185¼	

upon inefficient principles, and require the introduction of the absolute block system.

The following table gives the details relating to the block system and mileage of all the principal railways, and shows that considerable progress has been made—

—	Total length of line opened for passenger traffic.		Distance worked upon the absolute block system.	
	Double.	Single.	Double.	Single.
	Miles.	Miles.	Miles.	Miles.
Cheshire lines	115	—	96	—
Furness.	72	34	71	34
Great Eastern	494	479	494	221
Great Northern	570	109	570	99
G.N. and G.E. Joint . . .	111	5	111	5
Great Western	1,064	1,029	973	785
Lancashire and Yorkshire .	424	16	424	9
London and N.W.	1,375	303	1,360	273
L. and N.W. and Gt. Western Joint	111	27	111	21
London and S.W.	541	207	541	199
London, Brighton, and South Coast	342	118	342	118
London, Chatham, and Dover.	167	10	167	10
Manchester, Sheffield, and Lincolnshire	265	3	218	—
Midland	993	273	957	212
North-Eastern	921	449	914	436
North Staffordshire. . . .	150	18	144	18
South-Eastern	347	41	347	41
Somerset and Dorset Joint .	13	78	13	78*
Taff Vale	52	12	6	1
Caledonian	427	291	421	198
Glasgow and S.W.	233	109	225	67
Great North of Scotland . .	23	275	23	269*
Highland	6	411	6	411*
North British	401	469	380	139
G.N. of Ireland	136	375	3	14
G.S. and Western	206	301	49	17
Midland Great Western . .	148	275	70	35

* The Somerset and Dorset, Highland, Great North of Scotland, and some minor railways work single lines by "crossing orders," instead of the train staff, and at the present time a signalman is undergoing six months' hard labour in connection with that dangerous crossing system.

APPENDIX III.

THE CONTINUOUS BRAKES RETURN.

Report by Mr. Clement E. Stretton, Consulting Engineer, to the General Secretary of the Amalgamated Society of Railway Servants.

[Copy.]

Leicester,
October 28, 1886.

Dear Sir,—In accordance with the wish expressed in your letter of the 20th instant, I have carefully examined the Continuous Brakes return for the first half of the year 1886, which has, since the meeting of the Congress at Brighton, been issued by the Board of Trade. It again furnishes evidence (if any were required) that the companies are not taking the necessary steps to arrive at the use of a general system, and it is very unsatisfactory to find that a considerable amount of rolling stock has during the past half-year been fitted with inefficient non-automatic brakes which make no claim to fulfil the conditions laid down by the Board of Trade, thus practically placing that department of the Government at defiance.

I have drawn up the following tabulated statement, showing at a glance the amount of stock fitted and unfitted on the 30th June, 1886:—

—	Engines fitted with brakes.	Engines fitted with apparatus for working the brakes	Carriages, &c., fitted with brakes.	Carriages, &c., fitted with pipes or chains only.
Total amount of stock returned as fitted with brakes which appear to comply with conditions of Board of Trade .	2,604	1,376	22,230	4,623
Total fitted with brakes which do not comply	1,216	1,435	13,111	3,274
Total fitted .	6,631		43,238	
Not fitted with any continuous brake .	849		8,552	
Total passenger rolling stock therefore .	7,480		51,790	

From these figures it will be seen that out of a total of 7,480 engines and 51,790 carriages, &c., only 2,604 engines and 22,230 vehicles have brakes which even "appear" to fulfil the Board of Trade conditions, and from a further examination of some of the brakes I am able to report that a large number of vehicles returned as efficient are not so in actual practice. This latter fact appears to be known to the Board of Trade, as on page 28 the return states in a footnote, "These totals are the numbers of engines and carriages returned by the railway companies as fitted with continuous brakes. It will be observed, however, that some of the brakes so returned but very imperfectly fulfil that designation."

A careful examination of the return shows that it is so full of incorrect statements that for all practical purposes of comparison it is absolutely useless. For instance, the North London Company reports that the

Clark and Webb chain brake fulfils the necessary conditions, whereas the London and North-Western makes no such claim.

The Midland and Great Western Companies include a large amount of rolling stock as fulfilling the conditions, which is fitted with the dangerous "leak-off" or two-minute vacuum brake. It is hardly necessary to here report that this system is not efficient, as the numerous accidents which have been caused by it and the reports of the Board of Trade inspectors have clearly proved this fact.

The Midland Company has fitted 175 passenger engines and tenders with what the return calls an automatic steam brake, working in conjunction with the vacuum brake on the train. I have examined and tested the appliance, and find that although it may do very well under ordinary circumstances, it is absolutely useless in case of disaster, as the moment the engine and tender part, the steam pipe is broken, and the so-called automatic steam brake fails to act; therefore it does not fulfil the important condition of being efficient and self-acting in case of accident.

The tabulated statement which will be found on page 3 of the return is incorrect and very misleading. The totals given include engines fitted with *apparatus* for working the brakes, and vehicles which have only through pipes, but no brake blocks. Such rolling stock does not fulfil any condition, as there can be no possible brake power when an engine has simply the apparatus for working brakes on carriages and no blocks on its wheels; neither can vehicles with *pipes* only be of any value in case of accident. I have now before me details of a recent case in which a train was

sent out with an engine with no blocks on its wheels, and eighteen vehicles, fourteen of which had through pipes only. Such a train would be returned to the Board of Trade as working a certain number of miles with a continuous brake; but in fact it was almost in as bad a position, as regards stopping power, as a train without such a brake; and so long as horse-boxes, fish-trucks, and other vehicles are run in passenger trains it is essential to safety that they should be provided with the continuous brake gear complete. If, therefore, the inefficient systems, and the engines with apparatus, and vehicles with pipes, be deducted from the brakes which "appear" to comply with the conditions, the unsatisfactory aspect of the brake question will be very clearly seen. The policy of the London and North-Western Company in removing the Clark and Webb chain brake, and substituting the simple vacuum, which does not comply with the conditions, is most unsatisfactory, as it is but a waste of a large amount of shareholders' money, for without doubt this vacuum brake will at some future time either have to be entirely removed or altered to an automatic system at a further cost. The Manchester, Sheffield, and Lincolnshire Company's return shows that it is continuing the use of the same Smith's vacuum brake which led to the death of twenty-four persons and injury to sixty-two at Penistone two years ago. Another accident occurred at Penistone on 1st September last, when part of an express train ran back, coming into collision with a waggon standing in a siding near the buffer stops, thus causing injury to twenty-four persons; and from my examination of the place and the facts, I have no doubt whatever that if the train had been fitted with

an automatic brake the accident would not have taken place. For some time past it has been well known to the Amalgamated Society that certain companies will never settle or attempt to settle the brake question until compelled to do so. It is therefore to be hoped that Parliament will deal with Mr. Channing's Bill at an early date next session.

The returns relating to brake *failures* are, as upon previous occasions, very incorrect; a large number of cases, of which the Society has details, are not reported at all, and others are either placed under the wrong headings, or are even charged to the wrong brakes. It is also important that the companies should be required to furnish the *name* of the place where the failure occurs, as without this information it is impossible to trace a case, or to know if it is or is not reported. The Metropolitan Company, for instance, gives twelve cases in which "a train overran the platform of *a station*," through the failure of Smith's vacuum brake. The Great Eastern, and Glasgow and South-Western, also omit the names of stations.

The Lancashire and Yorkshire Company report an actual failure to act on 25th February at Hindley simply as one of delay, whereas it is a case which ought to have been recorded under Class 2. The same company records ball-valves and vacuum apparatus out of order, as belonging to the Westinghouse brake. The Midland Great Western of Ireland reports three failures of Smith's vacuum brake simply as delays, but they belong to Class 2, as the trains ran past stations six, five, and eleven carriage lengths respectively.

During the half-year there have been three collisions reported caused by failures of continuous brakes.

(1) The vacuum pipes on a Great Northern train became uncoupled, and a collision with the buffer stops at Kirkstead was the result. (2) A North-Western train ran into the buffer stops at Sutton Coldfield, owing to the breakage of the stalk of the ejector of the vacuum brake. (3) The coupling of a North-Western engine broke near Birmingham, and the carriages ran into the engine, as the vacuum brake failed to stop them. It is hardly necessary to point out that these three accidents could not have occurred if the Great Northern and North-Western companies had employed brakes which are automatic in action.

The Board of Trade requires that the returns relating to brake failures should be placed under one of three heads, as follow: (1) Failure or partial failure of the continuous brakes to act when required in case of an accident to a train, or a collision between trains being imminent. (2) Failure or partial failure of the continuous brakes to act under ordinary circumstances to stop a train when required. (3) Delay in the working of trains in consequence of defects in, or improper action of, the brakes, distinguishing whether they arose from neglect or inexperience of servants, or failure of machinery or material.

It would be a very great advantage if the totals of each brake, under each heading, were placed in a summary or tabulated form, as at present the information extends over fifty-eight pages of the return, and therefore cannot be easily compared. The London, Brighton, and South Coast Railway reports that five accidents have during the half-year been avoided by the use of the Westinghouse automatic brake.

The working of the Steel-McInnes brake has become

practically extinct; it has been removed from the three engines upon the Caledonian to which it was fitted, and its removal from the carriages is now being carried out.

In view of the very unsatisfactory manner in which the companies make their returns, I trust the Board of Trade will appoint a committee, as suggested by the recent Congress, to examine and report upon the various brakes.

In this report I have only dealt with a few of the incorrect and misleading statements, but sufficient has been said to prove to you and to the Society that for all practical purposes the Board of Trade return has been rendered valueless.—I am, yours faithfully,

(*Signed*) CLEMENT E. STRETTON,
Consulting Engineer A.S.R.S.

To E. Harford, Esq.,
General Secretary A.S.R.S.,
306, City Road, London, E.C.

APPENDIX IV.

MIXED TRAINS.

FOR several years past the Amalgamated Society has strongly condemned the running of mixed passenger and goods trains, and has urged that, if such trains are run, the passenger carriages should at least be placed in the safest place, near the engine, and in front of the waggons.

Several accidents have recently occurred, and it is satisfactory that the following circular has been issued.

[*Copy.*]

R.4,163.

"Board of Trade, Railway Department,
"London, S.W., 25th August, 1886.

"SIR,—The attention of the Board of Trade has been specially directed by some of the reports which have recently been received from their inspecting officers to the practice of running mixed trains in which passenger carriages have been attached to goods waggons. The facts brought to their notice in these reports have borne out the opinions expressed in previous reports as to the dangers arising from the running of mixed trains, especially when goods or other waggons are placed between the engine and the passenger carriages. The inspecting officers report that the risk of so placing the passenger carriages outweighs the advantages which may in some cases of accident to the front of the train have resulted from the waggons taking the worst of the shock. In these circumstances the Board of Trade wish to call the attention of the directors of the —— Railway Company to the desirability of avoiding, as far as may be, such a practice. If the running of mixed trains is not altogether avoidable, care should be taken that any waggons attached to such trains are specially constructed for the purpose, and fitted with such appliances as are generally adopted in the case of passenger carriages. The Board of Trade trust that, when the condition of the traffic necessitates the running of mixed trains, the passenger carriages will, as far as possible, be placed in front and not to the rear of goods waggons, and that all other precautions will be taken to lessen the risk of conducting traffic on such a system.

"I am, Sir, your obedient servant,
"COURTENAY BOYLE.

"To the Secretary of the —— Railway Company."

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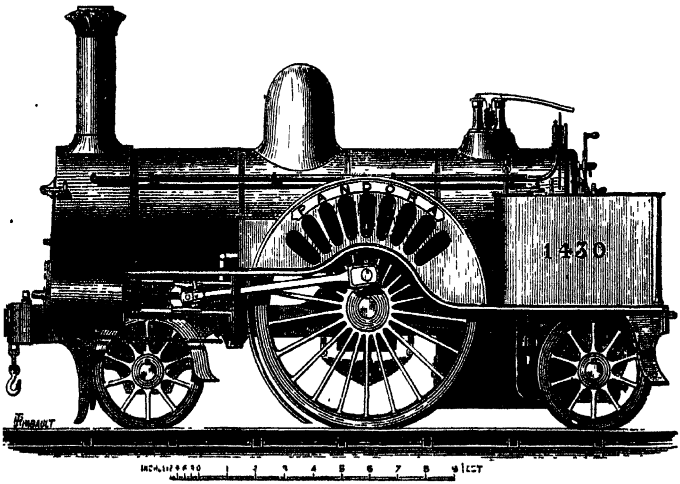

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